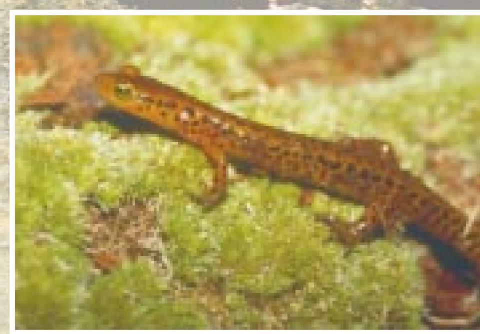
STATE OF THE STREAMS



1995-1997 MARYLAND BIOLOGICAL STREAM SURVEY RESULTS

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STATE OF THE STREAMS:

1995-1997 MARYLAND BIOLOGICAL

STREAM SURVEY RESULTS

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FOREWORD

This report, *State of the Streams: 1995-1997 Maryland Biological Stream Survey Results,* supports the Maryland Department of Natural Resources' Maryland Biological Stream Survey (MBSS) under the direction of Dr. Ronald Klauda and Mr. Paul Kazyak of the Monitoring and Non-Tidal Assessment Division. This report was prepared under Maryland's Power Plant Research Program(Contract No. PR-96-055-001 to Versar, Inc.). Development of the statewide estimates of stream condition in this report was supported by the U.S. Environmental Protection Agency, Office of Research and Development, Regional Environmental Monitoring and Assessment Program (R-EMAP), through funds provided to Maryland DNR (Contract number Ca-98-11, 07-4-30528-3734, University of Maryland subcontract to Versar, Inc.). A major goal of the MBSS is to assess the impacts of acidic deposition on Maryland's headwater streams and their biological resources. The MBSS is also designed to characterize and assess biological, physical habitat, and water quality conditions of streams throughout the entire state, based on a three-year implementation schedule (1995-1997). This report presents statewide results from the 1995-1997 MBSS sampling years. This report includes a characterization of stream conditions, assessments based on ecological indicators, and analyses of the associations between human impacts and stream ecological conditions.

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EXECUTIVE SUMMARY

This report summarizes results from the 1995-1997 sampling of the Maryland Biological Stream Survey (MBSS or the Survey) and provides the first statewide results on the assessment of the condition of Maryland's non-tidal streams. Supported and led by the Maryland Department of Natural Resources (DNR), the MBSS is a comprehensive program to assess the status of biological resources in Maryland's non-tidal streams; quantify the extent to which acidic deposition has affected or may be affecting critical biological resources in the state; examine which other water chemistry, physical habitat, and land use factors are important in explaining the current status of biological resources in streams; establish a benchmark for long-term monitoring of trends in these resources; and target future local-scale assessments and mitigation measures needed to restore degraded biological resources. To meet these and other objectives, the Survey has established a list of questions of interest to environmental decision makers to guide its design, implementation, and analysis. These questions fall into three categories: (1) characterizing biological resources and ecological conditions (such as the number of fish in a watershed or the number of stream miles with pH < 5), (2) assessing the condition of these resources (as deviation from minimally impacted expectations), and (3) identifying likely sources of degradation (by delineating relationships between biological conditions and anthropogenic stresses).

To answer these questions, a number of steps were undertaken to implement the Survey, including (1) devising a sampling design to monitor first- through third-order nontidal streams throughout the state and allow areawide estimates of the extent of the biological resources, (2) field testing sampling protocols and logistical arrangements to assure data quality and precision, (3) conducting an extensive, multi-year field sampling program, (4) developing indicators of biological condition (or integrity) so that degradation can be evaluated as a deviation from reference (or minimally impaired) expectations, and (5) using a variety of analytical methods to evaluate the contributions of different anthropogenic stresses, including land use. Completion of the 1993 MBSS Pilot Study and the 1994 MBSS Demonstration Project successfully addressed the design and sampling issues and provided preliminary results. In 1995, the first year of the three-year implementation of the Survey, research efforts focused on the development of biological indicators and better fish population estimation techniques. In 1996, the second year of implementation, these advances were applied to new data and enhanced analyses were conducted, including incorporation of more precise land use data. The final three-year report builds upon the previous years of the Survey. In addition to utilizing a refined fish Index of Biotic Integrity (IBI), this report presents the results of a newly developed benthic IBI and a Physical Habitat Index (PHI). These three indices are the basis for estimating the number of stream miles in varying degrees of degradation (good to very poor condition) and mapping the locations of sites by their condition.

Three characteristics of the Survey differentiate it from previous stream monitoring efforts in Maryland. First, sampling in the Survey is probability-based, allowing accurate and robust population estimates of variables such as abundances of particular species of fish and the number of stream miles with degraded habitat. The probability-based sampling design also permits estimation of sampling variance, so that estimates of status can be made with quantifiable confidence. Second, MBSS monitoring and assessments focus on biological responses to stress. Metrics for characterizing pollutant stress and habitat condition are measured simultaneously to provide a context for interpreting biological response. Third, the scale of the Survey is basinwide and statewide, rather than local. However, MBSS data can be used to assess stream condition at a county level and even for some smaller watersheds.

The Survey uses a special probability-based survey design called lattice sampling to ensure that non-tidal streams within all of the state's river basins can be sampled over a three-year period. The lattice design effectively stratifies by year and basin and restricts the sampling each year to about one-third of the state's 17 major drainage basins. This restriction is used to optimize the efficiency of the field effort by minimizing the travel time between sampling locations. Approximately 300 stream segments of fixed length (75 m) are sampled each year, with biological, chemical, and physical parameters measured at each segment using standardized methods. Biological measurements include the abundance, size, and individual health of fish; taxa composition of benthic macroinvertebrates; and presence of amphibians and reptiles, mussels, and aquatic vegetation. Chemical measurements include pH, acid-neutralizing capacity (ANC), sulfate, nitrate, conductivity, dissolved oxygen, and dissolved organic carbon (DOC). Physical habitat parameters include commonly used observational measurements such as instream habitat structure, embeddedness, pool and riffle quality, bank stability, shading, and riparian vegetation, and quantitative measurements such as stream gradient, maximum depth, wetted width, and discharge. Other qualitative parameters measured at each site include aesthetic value, remoteness, and land use immediately visible from the segment. Additional land use information for the entire catchment upstream of each sample site was incorporated into the Survey from statewide geographic information system (GIS) coverages.

This 1995-1997 report presents the final results of the three-year cycle of sampling that completes the first round of the Survey. It documents the sampling of 955 segments in 17 of the state's major drainage basins and provides for statewide estimates of stream quality. The report first describes the environmental setting of Maryland, placing the results in the context of their geologic, climatic, and human history. It then characterizes stream conditions by estimating average conditions in each basin for most of the measured variables and by calculating the percentage of stream miles where one or more thresholds for selected variables were exceeded. It also assesses the quality of the streams by estimating the number of stream miles in each basin that meet the Index of Biotic Integrity (IBI) thresholds for good to fair fish and benthic macroinvertebrate communities based on the reference condition for that region. Relationships between specific characteristics of these streams, including the fish and benthic IBIs, and potential anthropogenic stresses are investigated. These major stressors include physical habitat degradation, acidification, nutrients, and land use impacts. A brief discussion is included of how MBSS results vary among sample years and implications for interpreting the results. A separate chapter uses the 1995-1997 MBSS results to discuss the condition of Maryland's aquatic biodiversity.

The geologic history, climate, physiography, geology, soils, and human influences on the landscape provide a useful context for assessing Maryland streams. As a result of glacial and post-glacial landform erosion, there are two major drainages in Maryland today: the Chesapeake Bay which empties into the Atlantic Ocean and the Youghiogheny River, which ultimately drains to the Mississippi River. All but one of the major river basins in Maryland drain into the Chesapeake Bay. Because these basins form natural ecological and aquatic management boundaries, they are the primary reporting units used for the Survey. Since the time of the last glaciation, a number of climatic events have occurred that have likely influenced the distribution of aquatic biota. It is important that MBSS and other data be interpreted in the context of such past abiotic conditions, even if the conditions only persist for weeks or days. Variations in precipitation, temperature, physiography, geology, and soils are also important when interpreting the results of the 1995-1997 MBSS. Human influences upon water quality extend to every part of the state. Practices such as forest management, agriculture, urbanization, and mining have had significant impacts upon both air and water quality in Maryland. The history of human influences on Maryland streams sets obvious limits on the number of high quality streams that can be preserved and the level of integrity to which they can be restored. Therefore, it is critical that natural resource managers develop an appropriate vision of desired conditions for Maryland streams and view the results of the Survey in that context.

During the 1995-1997 MBSS, 83 fish species were collected at the stream segments sampled using the MBSS stratified random sampling design. Occurrences not often reported included the endemic checkered sculpin (found in the Middle Potomac and Upper Potomac basins) and the non-native cutthroat trout (found in the North Branch Potomac and Patapsco basins). The density (number of individuals per stream mile) and abundance (number per basin) of individual game and non-game fish species were calculated from double-pass electrofishing data and corrected for capture efficiency. Statewide, the most abundant stream fishes were blacknose dace and mottled sculpin. Fish species richness per segment increased two-fold from the most western basin to the central basins and by four-fold in the eastern basins. Fish biomass followed a similar pattern. Gamefish abundance and distribution varied geographically and by stream order, with largemouth bass and brook trout by far the most abundant gamefish captured. Evidence indicates that the brook trout and American eel (an economically important species) have experienced precipitous declines as a result of human activities. Among all fish, external pathological abnormalities were observed infrequently. Statewide, 346 benthic macroinvertebrate genera within 112 families were collected. In general, basins on the Coastal Plain contained fewer benthic taxa than elsewhere in the state. Amphibians were present in approximately 50% of stream miles and salamander species richness was significantly greater in first- and second-order streams than in third-order streams. Eight species of freshwater bivalves were found throughout the state during 1995-1997 sampling. The Asiatic clam, a species introduced to Maryland in the 1930s, was found in 13 of the basins sampled. Twenty-four distinct species of aquatic vegetation were found. Aquatic plant species richness was highest in low-gradient, less shaded streams in the Coastal Plain.

Fish IBI scores for stream sites sampled in the 1995-1997 MBSS spanned a wide range of biological conditions, from good to very poor. Statewide, 45% of stream miles fell into the range of good to fair. An estimated 29% showed degradation (poor to very poor condition). The remaining 26% were not rated with the fish IBI because of small stream size. In the North Branch Potomac basin, 40% of the stream miles exhibited some level of degradation, while six basins (Gunpowder, Bush, Elk, Choptank, Nanticoke/Wicomico, and Pocomoke) had no sites with IBIs rated as very poor and less than 25% rated as poor. First-order streams had a smaller percentage of stream miles rated as good or fair than did larger streams.

Benthic IBI scores for the stream sites sampled in the 1995-1997 MBSS also spanned a wide range of biological conditions, from good to very poor. Statewide, 49% of stream miles fell into the range of good to fair, while 51% showed signs of degradation (poor to very poor conditions). The West Chesapeake basin contained 70% of stream miles rated very poor, while the Susquehanna basin had no sites rated very poor. As with the fish IBI, first-order streams had a smaller percentage of stream miles rated as good or fair than did larger streams. According to the Hilsenhoff Biotic Index (a benthic macroinvertebrate indicator of organic pollution), 78% of stream miles statewide were in good or fair condition using this indicator, while only 19% were in poor or very poor condition. The remaining 3% of stream miles were not rated using the Hilsenhoff Biotic Index because of small samples. All three of these biological indicators showed significant positive relationships to each other, although there was a large amount of variation at the statewide level.

The analysis of 1995-1997 MBSS data looked closely at physical habitat degradation of Maryland streams. Statewide, 28% of stream miles had no effective riparian buffer vegetation. An estimated 40% of stream miles had at least a 50 m vegetated riparian zone. An estimated 58% of all stream miles had forest cover and 14% had other types of vegetation in the riparian zone. Statewide, an estimated 4% of stream miles had beaver ponds, with the highest occurrence in the Lower Potomac basin (16%). Channelization occurred at an estimated 17% of stream miles in the state, with the highest occurrence in the Pocomoke basin (82%). Several instream condition parameters were also sampled during the 1995-1997 MBSS.

The Physical Habitat Index (PHI) is a reference-based indicator that combines many of the habitat metrics. PHI scores for stream sites sampled in the 1995-1997 MBSS spanned a wide range of biological conditions, from good to very poor. Statewide, 49% of stream miles were rated either good or fair and 51% were rated poor or very poor. The Elk basin received the best PHI rating, with 50% of stream miles in good condition and no stream miles in very poor condition. The West Chesapeake basin contained the largest percentage of stream miles in very poor condition (78%). A significant positive relationship was found between PHI and both the fish and benthic IBIs, indicating that physical habitat quality plays an important role in the health of fish and benthic macroinvertebrate communities. Although no indicator has been developed for amphibian and reptile species, their numbers did increase with PHI scores and with the width of the riparian buffer. Several individual habitat metrics were also correlated with IBI scores. Fish IBI scores were strongly related to instream habitat structure and maximum depth. Benthic IBI scores were most strongly correlated with riffle quality. Both indicators were correlated with aesthetic quality, riparian buffer width, and channel alteration.

MBSS sampling in 1995-1997 provided new information on the extent to which acidic deposition affects stream chemistry and biological resources in Maryland streams. Statewide, 2.6% of streams sampled in the spring and 1.8% of streams sampled in the summer had a pH less than 5. First-order streams had a higher percentage of stream miles with low pH than larger streams. Statewide, approximately 28% of the stream miles were acidic (ANC < 0 μeq/l) or acid-sensitive (ANC 0-200 μeq/l), with more than 60% of stream miles acid-sensitive in five basins (Lower Potomac, Pocomoke, North Branch Potomac, Youghiogheny, and Choptank). The preponderance of acidic and acid-sensitive stream miles in the basins of Western Maryland and the Coastal Plain is consistent with the findings of the 1987 Maryland Synoptic Stream Chemistry Survey (MSSCS). In general, ANC values for the 1995-1997 MBSS are slightly higher than those in the 1987 MSSCS, indicating an improvement in acid-base chemistry in streams over time.

For the 1995-1997 MBSS, analyses were conducted to estimate the extent of impacts by acidic deposition, acid mine drainage, organic acidity sources, and agriculture. Acidic deposition was by far the most common source of stream acidification, dominating 19% of stream miles; acid mine drainage (AMD) was the dominant source in about 1.4% of stream miles. An additional 1% of stream miles were likely affected by both acidic deposition and AMD. Only 0.8% were dominated by organic sources, while another 1.7% were likely affected by both organic acids and atmospheric deposition. Agriculture accounted for the acidification of 4.2% of all stream miles. The effects of AMD were greatest in the North Branch Potomac basin where approximately 25% of stream miles were affected. Substantial biological effects of acidification were also evident. Statewide, fish and benthic IBI scores showed a marked decline with low ANC, a pattern paralleled by other biological characteristics including fish species richness, abundance, and biomass. Only six fish species were found at sites with pH < 5. The density of individual fish species decreased dramatically at ANC < 200 μeq/l and species composition appeared to shift in favor of acid-tolerant species.

Elevated nitrogen concentrations are one indicator of nutrient enrichment in aquatic systems. Excessive nitrogen loading may lead to the eutrophication of the receiving water body, particularly in downstream estuaries. Eutrophication often decreases the level of dissolved oxygen available to aquatic organisms. Prolonged exposure to low dissolved oxygen values can suffocate adult fish or lead to reduced recruitment. Statewide, the majority of stream miles (59%) had nitrate-nitrogen (NO_3-N) concentrations greater than 1.0 mg/l. An estimated 41% of stream miles had NO_3-N concentrations between 0.1 mg/l and 1.0 mg/l, and only 0.4% had concentrations that were less than 0.1 mg/l. The mean statewide NO_3-N concentration was 2.45 mg/l. The following basins had average NO_3-N concentrations greater than the statewide average: the Middle Potomac, Patapsco, Gunpowder, Susquehanna, Elk, Chester, Choptank, and Nanticoke/Wicomico basins. For the most part, these were the same basins with sites with NO_3-N concentrations greater than 7.0 mg/l. Statewide, the majority of stream miles (94%) contained dissolved oxygen concentrations that were greater than 5.0 ppm, a level generally considered healthy for aquatic life (also the water quality standard for Maryland). An estimated 3% of stream miles had dissolved oxygen concentrations that fell between 3.0 ppm and 5.0 ppm, while 3% had concentrations less than 3.0 ppm.

The CORE/Trend program, begun in 1974, is part of Maryland's long-term ambient monitoring of stream water quality. Surface water samples are collected monthly at 55 stations located throughout the state and analyzed for a variety of physiochemical parameters. Stations from the CORE/Trend program are located in 11 of the 17 basins in the State: the Youghiogheny, North Branch Potomac, Upper Potomac, Middle Potomac, Potomac Washington Metro, Patuxent, Patapsco, Gunpowder, Susquehanna, Chester, and Choptank. Overall, the statewide average NO_3-N concentration from the CORE/Trend data was 1.82 mg/l, while the average statewide NO_3-N concentration from the MBSS data was 2.45 mg/l. Average NO_3-N concentrations in the Youghiogheny and the North Branch Potomac basins were both consistently low, showing very little difference between monitoring programs. In the Upper Potomac and Patuxent basins, the average NO_3-N concentration was higher at the CORE/Trend stations than at the MBSS sites. In the remaining basins sampled by both programs, the NO_3-N concentration was higher at the MBSS sample sites than at the CORE/Trend stations. The greatest difference was in the Choptank basin where MBSS sites had an average NO_3-N concentration of 3.66 mg/l, while the CORE/Trend sites had an average concentration of 1.32 mg/l. Differences in values within individual basins were, in part, explained by differences in sample site locations.

Landscape analysis is a useful tool for examining potential cumulative effects on stream systems at a large geographic scale. For sites sampled in the 1995-1997 MBSS, associations between upstream land use (using the Multi-Resolution Land Characteristics data set) and biological indicators of stream condition were analyzed. The extent of urban land use was greatest among sites in the Patapsco (average 31% of catchment area upstream of individual MBSS sites in the basin) and Potomac Washington Metro (23%) basins, and far lower in the remaining basins. Agricultural land use was approximately 60% or greater at stream sites in the Susquehanna, Middle Potomac, Gunpowder, and Elk basins. Forest cover was most extensive for sites in the North Branch Potomac basin (83%).

The proportion of land uses in a watershed strongly affects stream water quality. Streams in urban areas with more impervious surface tended to have higher water temperatures than streams in either agricultural or forested watersheds. Streams in areas with more than 50% agricultural land use in the watershed tended to have three times the mean NO_3-N concentration than streams with less than 50% agriculture. Land use also significantly affected IBI scores. Nearly all sites with greater than 50% urban land use had IBI scores indicative of poor to very poor biological condition. Statewide, fish and benthic IBI scores tended to decrease with increasing urban land use. These relationships were the strongest in the Patapsco and Potomac Washington Metro basins where the percentage of urban land is the greatest. IBI scores also decreased with both low- and high-intensity development. Surprisingly, the fish IBI tended to increase with increasing agricultural land use, while the benthic IBI did not show a significant relationship with the amount of agricultural land in a catchment. Forest land use did not show a significant relationship to the fish IBI, although the high number of forested sites that are impacted by acidic deposition and AMD may confound this result. Forest land use was significantly correlated with the benthic IBI and removing sites that were impacted by acidic deposition and AMD made this relationship stronger. Wetlands, which occupy no more than 5% of a catchment area, were not significantly correlated to either the fish or benthic IBI. The Hilsenhoff Biotic Index showed similar relationships to all types of land use with the exception of agriculture. In this case, Hilsenhoff Biotic Index scores increased (indicating increased degradation) with an increased percentage of agricultural land. This result indicates that the Hilsenhoff Biotic Index may better detect the organic pollution associated with agricultural fertilizers, a compelling reason to use it as an ancillary indicator to the IBIs.

In order to determine how MBSS results for stream chemistry, physical habitat, and biological communities vary from year to year and with changes in weather conditions, year-to-year variability in several parameters was examined. Within the three basins resampled by the Survey in two different years (Youghiogheny, Patapsco, and Choptank), the mean value in each sample year for the fish IBI, benthic IBI, PHI, and nitrate-nitrogen concentration were examined. Although some small differences were detected, virtually all were within the range of error (±1 standard error). Statewide, Maryland received an average of 38% more rainfall than normal in 1996, while 1995 and 1997 each received an average of 7% less rainfall than normal. However, the large amount of rain that fell in 1996 did not result in predictably lower (or higher) values for any of the parameters examined.

This 1995-1997 MBSS report applies analyses using the fish and benthic IBIs to differentiate among the multiple contributing stressors of acidification, physical habitat degradation, nutrients, and land use on Maryland streams. Statewide, physical habitat degradation was the most extensive source of stress, affecting 52% of non-tidal stream miles. The relative ranking of the extent of other stressors was as follows: lack of riparian vegetation 28%, acidic deposition 21%, agricultural land use 17%, urban land use 12%, and acid mine drainage 3%. Overall, 72% of the sites sampled in the 1995-1997 MBSS were affected by at least one of these six stressors. The importance of these stressors varies considerably among basins and may combine in different ways to produce large cumulative effects on Maryland streams. A preliminary investigation was made into how the combined stressors affect the fish and benthic IBIs. Using multiple regression analysis, fish IBI scores decreased significantly with an increase in urban land use, nitrate-nitrogen concentration, and the presence of AMD. Fish IBI scores increased significantly with an increase in agricultural land use and with improved physical habitat quality. Neither the width of riparian vegetation (as measured within the 75-m segment) nor the presence of acidic deposition were significant factors for explaining variation in fish IBI scores statewide. Statewide, benthic IBI scores decreased significantly with an increase in urban land use and with the presence of AMD. Benthic IBI scores increased significantly with improved physical habitat quality and increased riparian buffer width. Surprisingly, benthic IBI scores also increased with the presence of acidic deposition. Neither the percentage of agricultural land nor the concentration of nitrate-nitrogen were significantly correlated with the benthic IBI in the multiple regression model. In order to examine site-specific stressors, a stressor matrix was created for the more than 500 sites with either a fish or benthic IBI score less than 3.0. The values obtained at each site for 32 parameters were arrayed in a matrix and compared to a threshold value for each parameter (e.g., urban land use > 25% or NO_3-N > 2 mg/l) to help identify potential stressors at each site.

Biodiversity is more than just the number of species or the IBI score of a stream, it is "the variety of life and its processes" at four scales (levels of organization): genetic, species, ecosystem, and landscape. At present, the Survey does not address genetic diversity, nor define the ecosystem or landscape types found in Maryland, but it does contain detailed information on the distribution and abundance of aquatic species (especially fish) and the communities in which they reside (as measured by species composition at stream sites). Information from the 1995-1997 MBSS on rare species, vulnerable fish populations, non-native fish species, fish hybrids, species diversity of several taxonomic groups, and general fish community types addresses aspects of both the ecological and evolutionary phenomena statewide.

Statewide species richness and distribution were examined for fish, benthic macroinvertebrates, reptiles and amphibians, mussels, and aquatic vegetation. For fish, the most species-rich sites were in the central part of the state, but were scattered over more than one-third of Maryland. Only three fish species (largemouth bass, bluegill, and pumpkinseed) were present in all 17 river basins. When the distribution of fish species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, 51 occurred in all three regions and less than 10 were unique to any one region. Only 14 benthic macroinvertebrate taxa were present in all 17 river basins. In no basin did the percentage of taxa unique to the basin exceed 10%. In general, the statewide pattern of total amphibian and reptile species richness declined from the western to eastern parts of the State. Only two amphibians (green frog and bullfrog) and one reptile (northern water snake)were present in all 17 basins. Only five basins contained more than two mussel species and the North Branch Potomac contained none. Only the Choptank basin contained more than ten aquatic plant species; three basins contained seven to ten species.

In the 1995-1997 MBSS, the presence of six rare fish (stripeback darter, glassy darter, mud sunfish, ironcolor shiner, logperch, and flier), one rare salamander (Jefferson salamander), and four rare mussels (alewife floater, northern lance, Atlantic spike, and squawfoot) listed by the state Natural Heritage program were recorded. Statewide, 16 of the basins contained at least one fish species with a population size of less than 500 individuals (i.e., potentially at risk of extirpation). For example, populations of redfin pickerel and creek chubsucker, two species common to Maryland's Coastal Plain, may be at risk in the Patapsco basin where what little Coastal Plain and wetland habitats occur in this basin appear to be suffering losses from anthropogenic activities. Hybridization sometimes occurs when species are brought together through range expansions or habitat homogenization (usually as a result of environmental degradation). In the Middle Potomac basin about 1% of the *Lepomis* collected were hybrids, while in the Bush basin about 0.1% of the cyprinids were hybrids. Where non-native species make up a large proportion of the number of species or individuals in a basin, the natural ecological or evolutionary processes of the fish communities have likely been substantially altered. The occurrence of non-native fish was greatest in the eastern part of the state, with all basins exceeding 50% of stream miles containing non-native fish species. In contrast, basins in Western Maryland contained the lowest percentage of stream miles with non-native fish species. Although non-native fishes made up a fairly small percentage of the total fish fauna, these non-native species were widespread geographically. The Asiatic clam, an introduced freshwater mussel species, was found in 13 of the 17 basins sampled, but at relatively few sites within each basin.

Recognizing that the Survey does not currently provide the classification of ecosystem and landscape types needed for a complete assessment of aquatic diversity, several kinds of results can be used to identify streams and stream networks that are noteworthy examples of naturally functioning community or ecosystem types. For the purposes of the 1995-1997 MBSS, "high-integrity" streams were defined as those having a fish or benthic IBI greater than 4.0. Statewide, 20% of stream miles were rated good by the fish IBI and 11% were rated good by the benthic IBI. Thirty-eight sites were rated good by both the fish IBI and benthic IBI. The 38 sites with highest biological integrity were distributed among 10 river basins with nine in the Youghiogheny and eight in the Lower Potomac basins. These sites likely represent some of the most natural stream ecosystem conditions in Maryland. High-integrity streams are even more likely to support natural ecosystem processes in the absence of non-native species. Stream sites with only native fish species are fairly evenly distributed across the State. However, only 56 of the 955 streams sampled in the 1995-1997 MBSS have only native fish species and high biological integrity (based on fish IBI scores). Twenty of these streams are clustered in the far western part of Maryland, while the others are scattered mostly in the central part of the State. High-integrity streams with natives only provide another potential focus for biodiversity conservation efforts. One such candidate "biodiversity hotspot" is the northwestern region of the North Branch Potomac basin in the mainstem Savage River. Five of the other basins also contained sites with high native species richness and no non-native species, but in each case the sites were disjunct and no areas of concentration were evident.

The goal of the MBSS is to provide environmental managers and policymakers with the information they need to make effective decisions. For this reason, the Survey was designed to best answer a set of 64 management questions. These questions represented the direction and range of natural resource management concerns in 1995. The results described in this 1995-1997 MBSS report provide scientifically defensible and management-relevant answers to the majority of these questions, in some cases the first such answers ever obtained. At the same time, certain management concerns have changed and programmatic needs have evolved. Some of the 64 questions are less important, while new questions need to be answered. This report summarizes the answers to original MBSS questions and to other questions of concern by the following topics: physical characteristics, water chemistry, biological resources, landscape characteristics, resource-stressor associations, and resource-landscape associations. It also describes the relevance of these answers to current natural resource management and policy initiatives. Specifically, the 1995-1997 MBSS provides Maryland DNR with its first comprehensive picture of Maryland's stream resources. Information on the abundance and geographic distribution of stream resources, especially aquatic biota, is valuable for many groups with mandates for or interests in protecting Maryland's streams. For example, the MBSS's statewide and basinwide estimates for each fish species can be used to supplement DNR Fisheries Service data and better target management efforts. The Survey provides statewide, statistically rigorous data on the abundance and distribution of fish that can be used to validate and supplement Natural Heritage Program information. Information on concentrations, or hotspots, of biodiversity components are already being used to support the Power Plant Research Program's (PPRP) Smart Siting initiative and the Maryland's Unified Watershed Assessment as part of the Federal Clean Water Action Plan.

Perhaps the most important information provided by the 1995-1997 MBSS is the answer to the question—What is the condition of the resource? By developing two reference-based biological indicators—the fish IBI and benthic IBI—the Survey provides unprecedented opportunities for identifying degradation anywhere in the state. Recently this information was used to help designate both Category 1 (priorities for restoration) and Category 3 (priorities for protection) watersheds within Maryland as part of the Unified Watershed Assessment. Ultimately, it may prove valuable for Maryland Department of the Environment's (MDE) water quality standards program and preparation of its 303d list of streams not meeting designated uses and to determine total maximum daily loads (TMDLs).

The Survey also provides a critical baseline for conducting future monitoring to address short-term and long-term trends. Already, the Survey determined that the extent of acid-sensitive streams in Maryland has declined slightly since the 1987 Maryland Synoptic Stream Chemistry Survey (MSSCS). This result has important implications for assessing the effectiveness of controls instituted as a result of the 1990 Amendments to the Clean Air Act. Future trends detection using the MBSS baseline monitoring data will likely prove invaluable for addressing continued population growth (supporting the Governor's Smart Growth initiative) and climate change.

By collecting all these parameters in conjunction with biological data at each stream site, the Survey has also been able to make accurate estimates of the relative contributions of different stressors and to begin to investigate the cumulative effects they have across the landscape. Ultimately, solutions to stream problems depend on effective controls on or remediations at the source of degradation. Information on potential stressors from the 1995-1997 MBSS will support a number of environmental protection efforts including DNR's Integrated Natural Resource Assessment, EPA's Mid-Atlantic Integrated Assessment, MDE's water quality program, and the Maryland Tributary Strategy Team's plans to reduce nutrients contributions to the Chesapeake Bay.

MBSS information can also help DNR select, design, and implement watershed restoration efforts. Recently, data from the 1995-1997 MBSS was incorporated into the Integrated Natural Resource Assessment to identify 11 watersheds that will be the focus of future restoration efforts by DNR's Watershed Restoration Division under the Clean Water Action Plan and other initiatives. In the future, MBSS data may help other targeting efforts, such as the Governor's commitment to restoring 600 miles of riparian vegetation in Maryland by the Year 2010.

Finally, this report closes with a discussion of the natural resource management questions that remain to be answered and the implications for future implementation of the Survey. DNR has begun planning for a second round of the Survey by developing a new set of management questions that reflect what has been learned in the first round of the Survey, as well as the evolution of management and policy concerns since 1995. To this end, the Monitoring and Non-Tidal Assessment Division has solicited comments from all parts of DNR on a draft set of management questions that will help shape future design and methods refinements. New management concerns likely to be incorporated into the next round of MBSS monitoring include comparing among sample rounds for trends detection; extending into smaller and larger streams, (while delineating more stream types); characterizing and assessing at finer geographic scales; better characterizing existing and new stressors; refining existing indicators and developing new ones; and improving identification of rare species and other biodiversity components.

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1 INTRODUCTION

This report presents the final results of a three-year cycle of sampling conducted by the Maryland Biological Stream Survey (MBSS or the Survey) to assess the "state of the streams" throughout the state. Previous reports documented interim results from the 1995 (Roth et al. 1997) and 1996 (Roth et al. 1997) sample years. This introductory chapter recounts the origin of the Survey, describes its components, and provides a roadmap to the report.

1.1 ORIGIN OF THE MBSS

More than 10 years ago, the Maryland Department of Natural Resources (DNR) recognized that atmospheric deposition was one of the most important environmental problems resulting from the generation of electric power. The link between acidification of surface waters and acidic deposition resulting from pollutant emissions was well established and many studies pointed to adverse biological effects of low pH and acid neutralizing capacity (ANC). Decreased growth and reproductive potential of adult fish and increased mortality rates of eggs and larvae were of greatest concern (Klauda 1989, Baker et al. 1990a, Morgan et al. 1991). To determine the extent of acidification of Maryland streams resulting from acidic deposition, DNR conducted the Maryland Synoptic Stream Chemistry Survey (MSSCS) in 1987. The MSSCS estimated the number and extent of streams at that time affected by or sensitive to acidification statewide. They concluded that the greatest concentration of fish resources at risk may be in streams throughout the Appalachian Plateau and Coastal Plain physiographic provinces (Knapp et al. 1988).

While the MSSCS demonstrated the potential for adverse effects on biota from acidification, little direct information was available on the biological responses of Maryland streams to water chemistry conditions. Data that were available could not be used (because of methodological differences and/or spatial coverage limitations) to compare conditions across regions or watersheds (Tornatore et al. 1992). Neither was it possible to assess the interactions between acidic deposition and other anthropogenic and natural influences (CBRM 1989). For these reasons, in 1993, DNR created the MBSS to provide comprehensive information on the status of biological resources in Maryland streams and how they are affected by acidic deposition and other cumulative effects of anthropogenic stresses.

1.2 DESCRIPTION OF THE MBSS

The MBSS is intended to help environmental decision-makers protect and restore the natural resources of Maryland. The primary objectives of the MBSS are to

- assess the current status of biological resources in Maryland's non-tidal streams;
- quantify the extent to which acidic deposition has affected or may be affecting biological resources in the state;
- examine which other water chemistry, physical habitat, and land use factors are important in explaining the current status of biological resources in streams;
- compile the first statewide inventory of stream biota;
- establish a benchmark for long-term monitoring of trends in these biological resources; and
- target future local-scale assessments and mitigation measures needed to restore degraded biological resources.

To meet these and other objectives of the MBSS, a list of 64 questions that the Survey will try to answer was developed (see Appendix A). These questions fall into three categories: (1) characterizing biological resources, physical habitat, and water quality (such as the number of fish in a watershed or the number of stream miles with pH < 5), (2) assessing the condition of these resources (as deviation from minimally impaired expectations), and (3) identifying likely sources of degradation (by delineating relationships between biological conditions and anthropogenic stresses).

Answering these questions has required a progression of steps in the implementation of the Survey, including (1) devising a sampling design to monitor non-tidal streams throughout the state and allow area-wide estimates of the extent of the biological resources, (2) implementing sampling protocols and quality assurance/quality control procedures to assure data quality and precision, (3) developing indicators of biological condition so that degradation can be evaluated as a deviation from reference expectations, and (4) using a variety of analytical methods to evaluate the relative contributions of different anthropogenic stresses.

In creating the Survey, DNR implemented a probability-based sampling design as a cost-effective way to characterize statewide stream resources. By randomly selecting sites, the Survey can make quantitative inferences about the characteristics of all 9,258 miles of first-to-third-order, non-tidal streams in Maryland (based on stream length on a 1:250,000-scale base map). The U.S. Environmental Protection Agency (EPA) is encouraging the use of random sampling designs to assess status and trends in surface water quality (EPA 1993). The initial MBSS design began with the MSSCS sample frame and was modified during the 1993 pilot and 1994 demonstration phases to provide answers to the questions of greatest interest (Vølstad et al. 1995, 1996). The final design allows robust estimates at the level of stream size (Strahler orders 1, 2, and 3), large watershed (17 river basins), and the entire state. Estimates by other categories, such as counties or smaller watersheds (138 in Maryland), are possible depending on the number of sample points in each unit.

DNR recognized that the utility of these estimates depended on accurately measuring appropriate attributes of streams. The Survey focuses on biology for two reasons: (1) organisms themselves have direct societal value and (2) biological communities integrate stresses over time and are a valuable and cost-effective means of assessing ecological integrity (i.e., the capacity of a resource to sustain its inherent potential). Inevitably, overall environmental degradation is tied to a failure of the system to support biological processes at a desired level (Karr 1993). It is equally important to recognize that the natural variability in biota requires that several components of the biological system be monitored.

Fish are an important component of stream integrity and one that also contributes to substantial recreational values. For these reasons, fish communities are the primary focus of the Survey. The Survey collects quantitative data for the calculation of population estimates for individual fish species (both game and nongame). These data can also be used to evaluate fish community composition, individual fish health, and the geographic distribution of commercially important, rare, or non-indigenous fish species. Benthic (bottom-dwelling) macroinvertebrates are another essential component of streams and they constitute the second principal focus of the Survey. The Survey uses rapid bioassessment procedures for collecting benthic macroinvertebrates; these semi-quantitative methods permit comparisons of relative abundance and community composition, and have proven to be an effective way of assessing biological integrity in streams (Hilsenhoff 1987, Lenat 1988, Plafkin et al. 1989, Kerans and Karr 1994, Resh 1995). The Survey also records the presence of amphibians and reptiles (herpetofauna), freshwater mussels, and aquatic plants (both submerged aquatic vegetation (SAV) and emergent macrophytes). The Survey has established rigorous protocols (Kazyak 1996) for each of these sampling components, as well as training and auditing procedures to assure that data quality objectives are met.

Although the MBSS sampling design and protocols provide exceptional information for characterizing the stream resources in Maryland, designation of degraded areas and identification of likely stresses requires additional activities. Assessing the condition of biological resources (whether they are degraded or undegraded) requires the development of ecological indicators that permit the comparison of sampled segment results to minimally impacted reference conditions (i.e., the biological community expected in watersheds with little or no human-induced impacts). The Survey has used its growing database of information collected with consistent methods and broad coverage across the state to develop and test indicators of individual biological components (i.e., fish and benthic macroinvertebrates) and physical habitat quality. Each of these indicators consists of multiple metrics using the general approach developed for the Index of Biotic Integrity (IBI) (Karr et al. 1986, Karr 1991) and the Chesapeake Bay Benthic Restoration Goals (Ranasinghe et al. 1994). The fish and benthic IBIs (which combine attributes of both the number and the type of species found) are widely accepted indicators that have been adapted for use in a variety of geographic locations (Miller et al. 1988, Cairns and Pratt 1993, Simon 1999). The Survey is investigating the possibility of developing additional indicators (e.g., amphibians in small streams with few or no fish) and combining components into a composite indicator of biological integrity.

In addition to developing reference-based indicators, the Survey is applying a variety of analytical methods to the question of which stresses are most closely associated with degraded streams. This involves correlational and multivariate analyses of water chemistry, physical habitat, land use, and biological information (e.g., presence of non-native species). The biological information also provides an unusual opportunity for evaluating the status of biodiversity across the state; the distribution and abundance of species previously designated as rare only by anecdotal evidence can be determined and unique combinations of species at the ecosystem and landscape levels can be identified. Land use and other landscape-scale metrics will play an important role in identifying the relative contributions of different stresses to the cumulative impact on stream resources. This report makes significant progress in quantifying known stresses and investigating their impacts on biological resources. Ultimately, the Survey seeks to provide an integrated assessment of the problems facing Maryland streams that will facilitate interdisciplinary solutions.

1.3 THE 1995-1997 STATEWIDE MBSS REPORT

This statewide report is the culmination of the progress made by the Survey over the last five years. In 1993, the Survey conducted a Pilot Study in four watersheds, two each in the Appalachian Plateau and Coastal Plain physiographic provinces (Vølstad et al. 1995). The Pilot Study evaluated the feasibility of conducting the random sampling program and developed estimates of the time requirements and costs to implement a full-scale Survey. In 1994, a Demonstration Project was conducted to refine logistics and protocols at the larger spatial scale needed for implementation and to determine which questions the program could successfully address with available resources (Vølstad et al. 1996). The Survey used information gained from the Demonstration Project to refine the study design to obtain the precision in the results needed to answer the questions of greatest interest, i.e., those at the scale of stream order or large watershed (river basin). The final sampling design was implemented over three years—1995, 1996, and 1997. The 1995 and 1996 MBSS reports presented the results of sampling in those years (i.e., for the basins sampled in those years), while this statewide report assesses all 17 basins and provides statewide estimates encompassing the full array of Maryland's ecological conditions.

The 1995-1997 MBSS incorporates and builds upon advances made over the 5-year life of the Survey. Estimates of fish abundance incorporate the results of double-pass depletion, a gear efficiency method developed for the 1995 MBSS that corrects for the relative capture efficiency of electrofishing different species (Heimbuch et al. 1997). The Index of Biotic Integrity (IBI) for fish, developed initially using MBSS data collected in 1994 and 1995 (Roth et al. 1998), has been refined and validated using later data. For the first time, the benthic IBI and physical habitat index (PHI) have been developed following the model of fish IBI development (using separate data sets for development and validation). These three indices are the basis for estimating the number of stream miles in varying degrees of degradation (good to very poor condition) and mapping the locations of sites by their condition.

The Survey has also developed a series of analytical techniques for characterizing biological communities, assessing their condition, and evaluating the relative contributions of different anthropogenic stresses. Previous MBSS reports have expanded the description of fish abnormalities (to address concerns about *Pfiesteria* outbreaks) and refined the narrative descriptions for the IBI categories (to improve their use for identifying impaired waters under the federal Clean Water Act). Investigation into the role of specific stresses in degrading Maryland non-tidal streams has improved in several ways. New analytical techniques were applied to determine whether the sources of acidification found in streams were acidic deposition or acid mine drainage. Additional parameters describing physical habitat condition were analyzed separately and as combined in the reference-based PHI. Information on nitrate-nitrogen concentrations in streams was evaluated and compared with data from the CORE/Trends program to address nutrient loading and downstream Chesapeake Bay concerns. Evaluations of the associations between stream parameters and land use in the upstream catchment draining to each stream site were added to provide a watershed context for addressing cumulative effects. The land uses in all of Maryland's 17 basins were characterized with the Multi-Resolution Land Characterization (MRLC) data set, information at a finer resolution than was available in 1995. In particular, low and high intensity developed areas were separated into separate land cover classes. Where possible, the Survey has looked at associations among multiple stresses and provided initial rankings of stresses based on their extent of influence (i.e., percentage occurrence in miles of stream).

Now that MBSS results from all three sample years (1995, 1996, and 1997) have been integrated, we have compared results among years and discussed the implications of interannual variability in precipitation and other factors. Statewide results also provide a better opportunity to describe the abundance and geographic distribution of rare species and other components of biodiversity. We have conducted additional biodiversity analyses to identify preliminary concentrations of species richness, rare species, and other areas supporting biodiversity. The statewide results in this report provide a framework for targeting areas for further assessment at a local scale, prioritizing areas for protection and mitigation of identified impacts, and monitoring restoration success or other trends in Maryland streams. To this end, a demonstration of species and indicator estimates at the county and small (138) watershed scales are included. The extent to which these analyses have answered the MBSS questions presented in Appendix A is discussed in the final two chapters of this report.

1.4 ROADMAP TO THIS REPORT

This report presents the results of the 1995-1997 statewide MBSS and includes 15 chapters and 8 appendices.

Chapter 2 provides a general description of the overall sampling design used by the Survey and describes the specific survey methods used. Chapter 2 also includes a brief description of the field and laboratory protocols and the statistical methods used in data analysis. Chapter 3 describes the environmental setting, placing the results in the context of their geologic, climatic, and human history. Chapter 4 characterizes Maryland's biological resources by taxa group; special attention is given to statewide fish estimates and discussions of important and declining species. Chapter 5 summarizes the results of assessing ecological condition using biological indicators (fish IBI, benthic IBI, and Hilsenhoff Biotic Index). Chapters 6, 7, 8, and 9 focus on issues affecting biological resources: acidification, physical habitat, nutrients, and watershed land use. Each of these chapters discusses the range of natural conditions and how they have been modified by human stresses in these categories. Chapter 10 is a brief discussion of how MBSS results vary among sample years and implications for interpreting the preceding results. Chapter 11 assesses the relative contributions of different stresses to the cumulative problems faced by Maryland streams. Chapter 12 analyzes the state of freshwater biodiversity, recognizing that rare species and other components are not captured by many of the MBSS indicators. The last two chapters summarize the conclusions of the statewide results and place them in the context of potential management and policy decisions (Chapter 13) as well as what questions remain to be answered (Chapter 14).

Appendix A contains a list of questions being addressed by the MBSS. Appendix B provides a table of the number of stream miles and sites sampled each year. Appendix C lists common and scientific names for all taxa collected in MBSS. Appendix D is a summary of the precipitation records for the 1995, 1996, and 1997 sample years. Appendix E provides summary tables with statewide estimates for habitat, water chemistry, and gamefish and non-gamefish populations. Appendix F is a table of all sample sites assessed as degraded with associated values for parameters that might indicate likely stresses. Appendix G is a table relating the 17 major drainage basins to the 138 small watersheds in the state and to Maryland's Tributary Strategies Basins. Appendix H contains tables listing the percentage of stream miles in each category of the fish and benthic IBIs as well as the Physical Habitat Index for the 24 Maryland counties and selected small watersheds.

2 METHODS

This section presents the specific study design and procedures used to implement the Maryland Biological Stream Survey (hereafter referred to as MBSS or the Survey). The study area of concern and the sampling design developed to characterize it are presented, along with field and laboratory methods for each component: water chemistry, physical habitat, fish, benthic macroinvertebrates, amphibians and reptiles, aquatic vegetation, and mussels. Quality assurance and statistical methods are described. This section also summarizes a capture efficiency adjustment for fish and various landscape evaluation methods used to increase the assessment and analysis capabilities of the MBSS. Methods for the formulation of the fish and benthic macroinvertebrate indicators, as well as for the physical habitat indicator, can be found in Chapters 5 and 6 of this report.

2.1 MBSS STUDY DESIGN

The MBSS is a multi-year, probability-based sampling program to:

- assess the status and trends of biological resources in non-tidal streams of Maryland;
- determine how they are affected by acidic deposition and other environmental factors;
- develop an inventory of ecological conditions; and
- aid in targeting restoration activities.

The Survey study area comprises 17 distinct drainage basins across the state (Figure 2-1). Random sampling allows the estimation of unbiased summary statistics (e.g., means, proportions, and their respective variances) for the entire state, a particular basin, or for subpopulations of special interest (e.g., all streams with pH < 5).

Because it would have been cost prohibitive to visit a sufficient number of sites in all basins in a single year, lattice sampling was used to schedule sampling of all basins over a three-year period. Lattice sampling, also known as multi-stratification, is a cost-effective means of allocating effort across time in a large geographic area (Cochran 1977, Jessen 1978). A table, or lattice, was formed by arranging 17 basins in 17 rows, and the years in 3 columns. Lattice sampling was the method used for selecting cells from this 17x3 table so that all basins would be sampled over a three-year period and all basins would have a non-zero probability of being sampled in a given year (Figure 2-1). Although originally included in the design as one of 18 basins originally included in the design, the Conewago basin was not sampled as part of the Survey's random sampling, because its small number of non-tidal stream miles would not permit accurate estimates of basin characteristics. However, in 1997, three sites chosen in a non-random manner in the Conewago basin were sampled using MBSS methods. Similarly, three non-random sites were sampled in the Ocean Coastal basin in 1997 to provide an overview of conditions there. The analyses in this report describe the results of random sampling for the 17 principal basins in Maryland. It does not include the results from supplemental sampling for fish that was conducted to augment the Survey.

The study area was divided into three geographic regions with five to six basins in each: (1) western, (2) central, and (3) eastern. This geographic stratification facilitated the effective use of three sampling crews from the different regions. Two basins were randomly selected (without replacement) from each region for sampling each year. One randomly selected basin in each region was visited twice, in order to quantify between-year variability in the response variables. A new set of randomly-selected sites was chosen for the repeat year. This controlled selection of cells from the lattice allowed estimation of average condition for all cells; (i.e., the average condition for all basins over a three-year period).

The sampling frame for the Survey was constructed by overlaying basin boundaries on a map of all blue-line stream reaches in the study area as digitized on a U.S. Geological Survey 1:250,000 scale topographic map. This sample frame was similar to that used by the earlier Maryland Synoptic Stream Chemistry Survey (MSSCS) conducted in 1987 (Knapp and Saunders 1987, Knapp et al. 1988). The Strahler convention (Strahler 1957) was used for ranking stream reaches by order; first-order reaches, for example, are the most upstream reaches in the branching stream system. Sampling was restricted to non-tidal, third-order and smaller stream reaches, excluding impoundments that were non-wadable or that substantially altered the riverine nature of the reach (Kazyak 1994). Together, these first- through third-order streams comprise about 90% of all stream and river miles in Maryland. Stream reaches were further divided into non-overlapping, 75-meter segments; these segments were the elementary sampling units from which biological, water chemistry, and physical habitat data were collected.

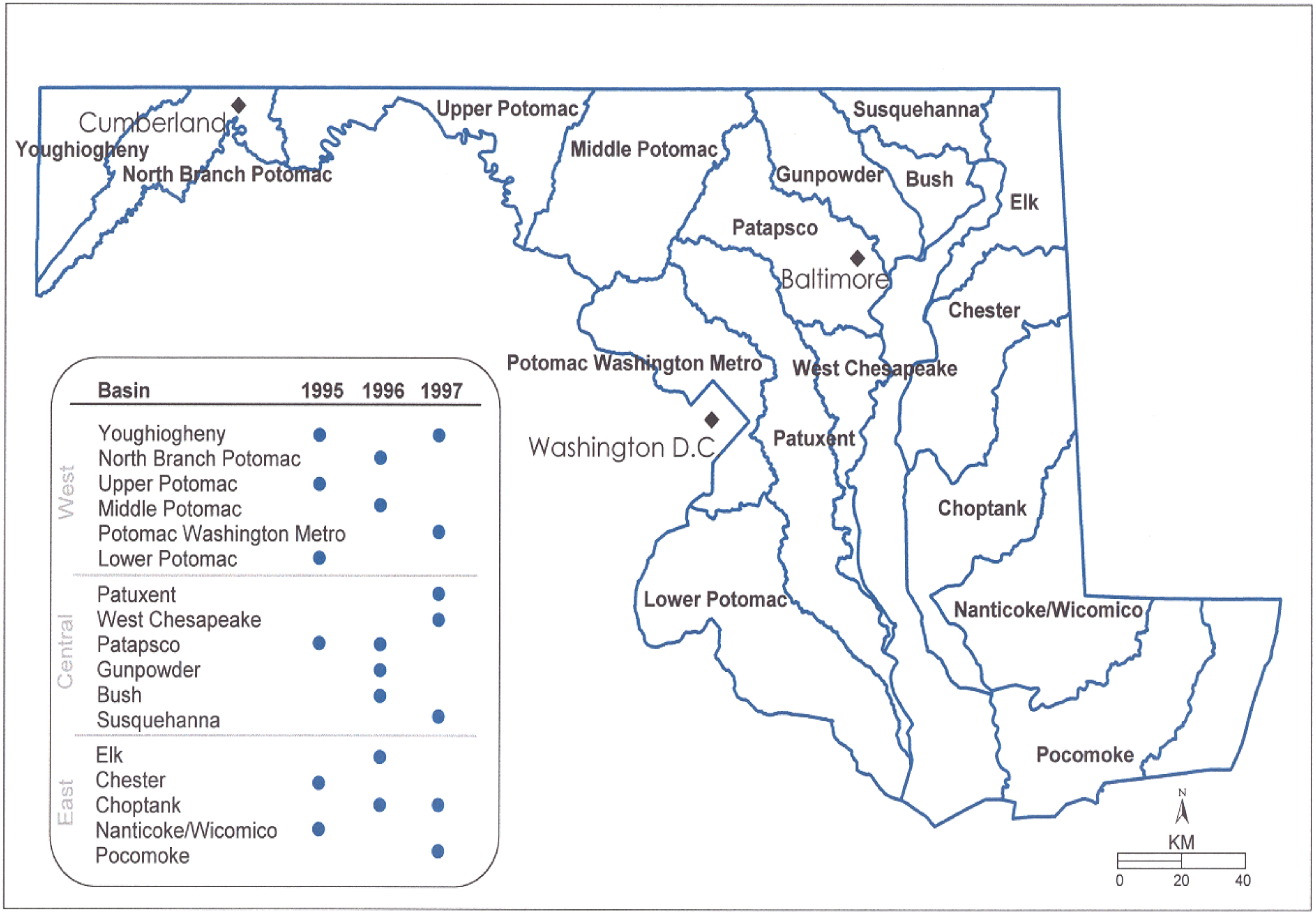


Figure 2-1. Basins in the MBSS study area and the years scheduled for sampling in the 1995-1997 survey

The 1995-97 MBSS study design was based on stratified random sampling of segments within each basin; each basin was stratified by stream order (Figure 2-2). Within a stream order, the number of segments sampled per basin is proportional to the number of stream miles in the basin (Appendix B, Table B-1). To achieve the target number of samples per stream order within each basin, a given number of segments were randomly selected from each basin and ranked in order of selection. In all basins, extra segments were selected as a contingency against loss of sampling sites from restricted access to selected streams or from streams that were dry, too deep, or otherwise unsampleable owing to field conditions. In some basins, where only a small number of sites would have been selected using this method, additional random sites were selected to increase sample size. These extra sites (selected at random using the method described above) were used to provide better basinwide estimates; they were not included in the estimates of statewide conditions.

Permissions were obtained to access privately owned land adjacent to or near each stream segment. The procedures for obtaining permissions are described in Chaillou (1995). Because landowner permissions were obtained in a synoptic fashion and some variation in these rates occurred, we obtained more permissions than were needed for the Survey. Only the highest ranking sites were sampled until the target goal for that basin was reached. For the three year study, the success rate for obtaining permission to access stream sampling segments was high. Eighty-eight percent of sites that were targeted for permission were sampled (Table 2-1). Reasons for permission denial varied widely and generally reflected the preferences of individual landowners regarding property access, rather than any specific types of land. In rare cases, permission denial may affect the interpretation of MBSS estimates, but only where denials occur in streams with characteristics that differ from the general population of streams. In one example of potential bias, several sites with known coal mining activities in the North Branch Potomac basin denied permission to sample, likely under representing the proportion of acid mine drainage in the population.

Table 2-1. Landowner permission success rates for basins sampled in the 1995-1997 MBSS

Basin	Number of Stream Segments Targeted as Potential Sample Sites	Success Rate
Youghiogheny 1995	71	75%
Youghiogheny 1997	46	78%
North Branch Potomac	90	86%
Upper Potomac	99	87%
Middle Potomac	165	87%
Potomac Washington Metro	94	97%
Lower Potomac	91	77%
Patuxent	103	93%
West Chesapeake	53	91%
Patapsco 1995	96	86%
Patapsco 1996	89	87%
Gunpowder	66	89%
Bush	45	87%
Susquehanna	45	94%
Elk	41	78%
Chester	82	93%
Choptank 1996	44	93%
Choptank 1997	33	94%
Nanticoke/Wicomico	62	100%
Pocomoke	58	94%
TOTAL	1,473	88%

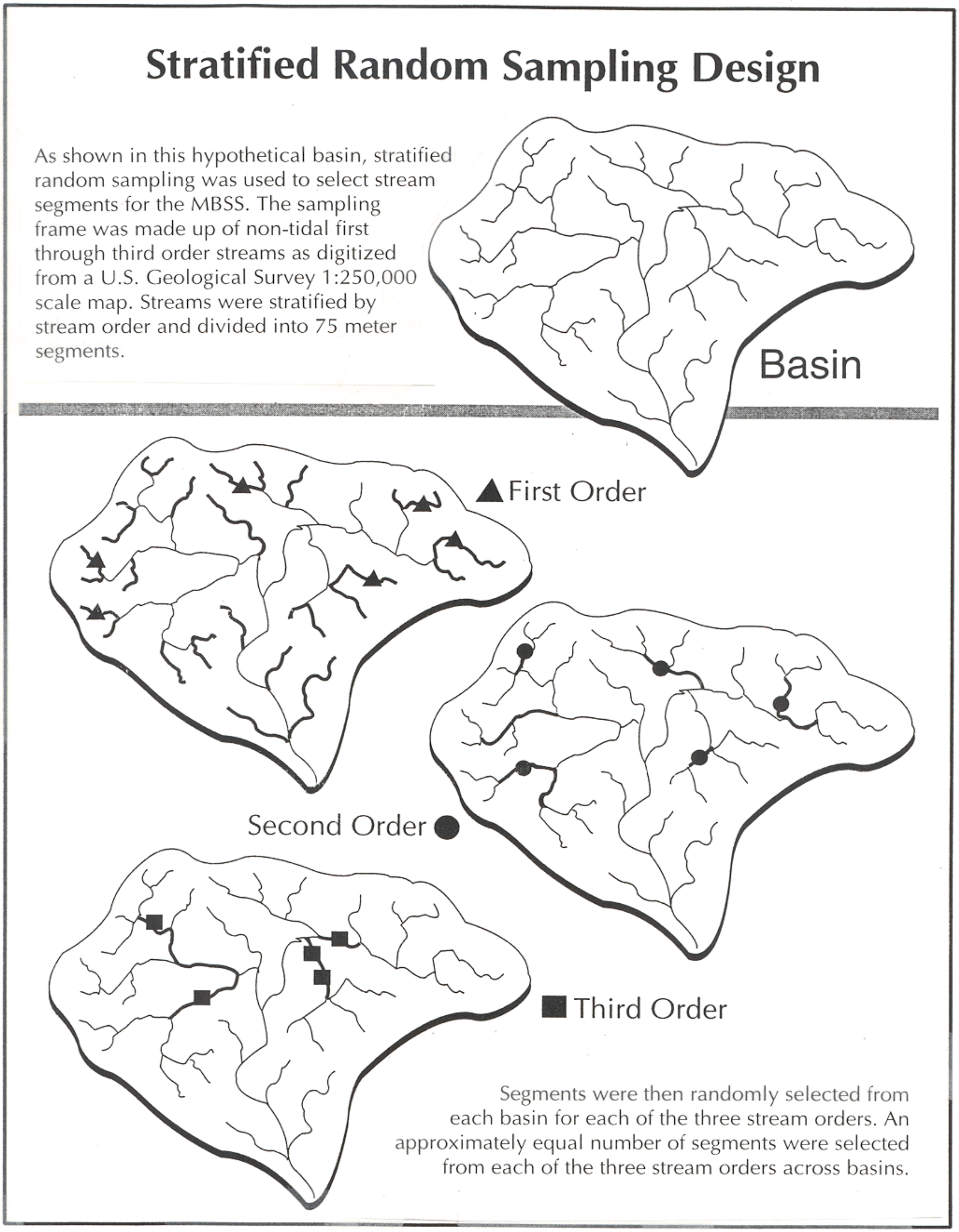


Figure 2-2. MBSS stratified random sampling design

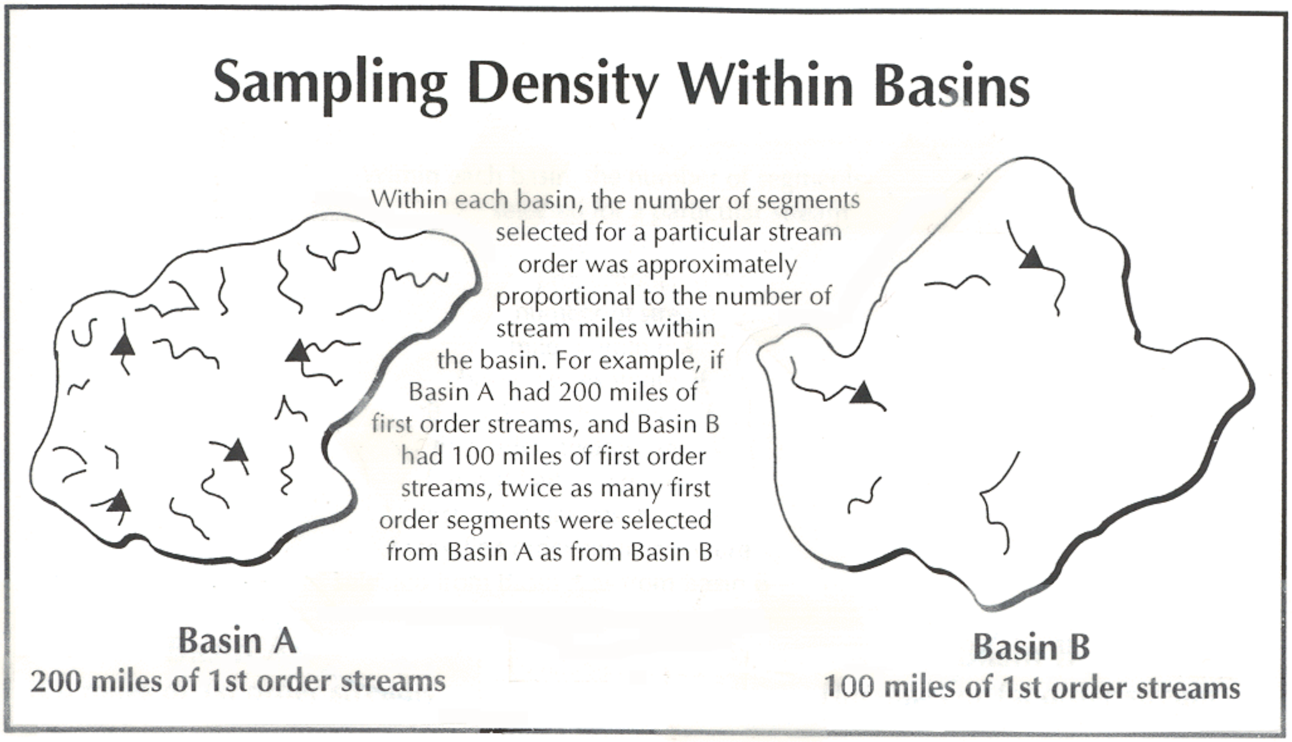


Figure 2-2. Continued

2.2 DESCRIPTION OF STUDY AREA

The Survey encompasses first-, second-, and third-order streams in Maryland, as determined from the 1:250,000 scale base map. It is important that the stream systems included in the Survey were precisely described in terms of the extent, location, and order of each type of stream. For the 17 basins sampled in the Survey, the number of first- through third-order stream miles ranged from 186 (Bush) to 1,102 (Middle Potomac) (Appendix B, Table B-1). The number of first-order stream miles (5,820) was about four times the number of second-order and eight times the number of third-order stream miles. Only by reference to these "total stream miles" can estimates of the percentage of the resource with specific attributes be converted to the total amount of the resource.

2.3 FIELD AND LABORATORY METHODS

In all, 955 stream segments were successfully sampled in the spring during 1995-1997; of those, 905 were also sampled in summer (Figure 2-3; Appendix B, Table B-2). Benthic macroinvertebrate and water quality sampling were conducted in spring, when the benthos are thought to be reliable indicators of environmental stress (Plafkin et al. 1989) and when acid deposition effects are often the most pronounced. Fish, amphibians and reptiles, aquatic vegetation, and mussel sampling, along with physical habitat evaluations, were conducted at 905 segments during the low-flow period in summer. Fish community composition tends to be stable during summer, and low flow is advantageous for electrofishing. Because low-flow conditions in summer may be a primary factor limiting the abundance and distribution of fish populations, habitat assessments were performed during the summer. The sample size in summer is lower than in spring because some streams were dry in summer or were, in rare cases, otherwise unsampleable.

To reduce temporal variability, sampling during spring and summer was conducted within specific, relatively narrow time intervals, referred to as index periods (Janicki et al. 1993). These index periods were defined by degree-day limits for specific parts of the state. This approach provided a synoptic assessment of the current status of stream biota, water quality, and physical habitat in the 17 basins sampled. The spring index period was the time period between approximately March 1 and May 1, with end of the index period determined by degree-day accumulation as

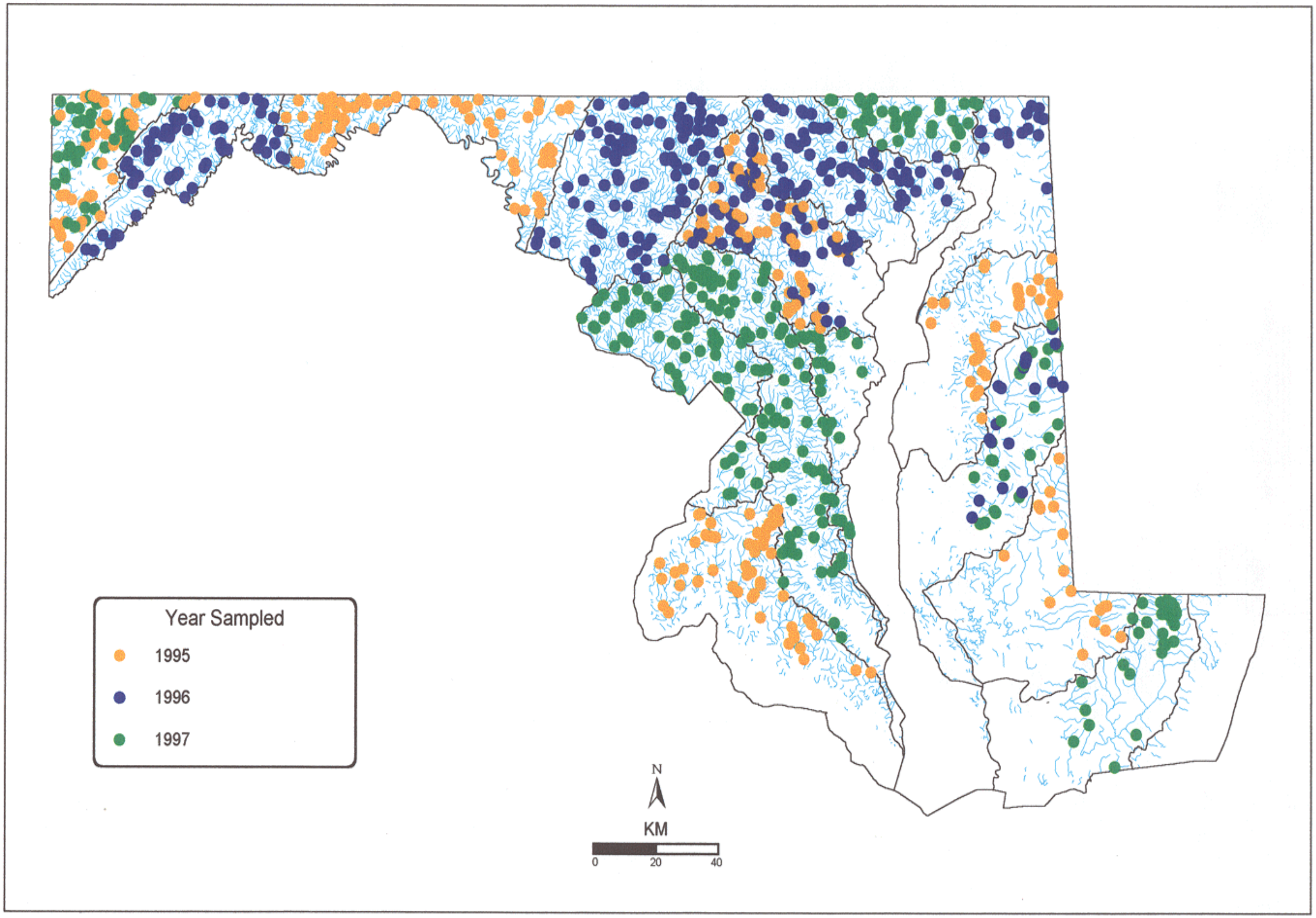


Figure 2-3. Randomly selected sites sampled in the 1995-1997 MBSS (955 sites)

specified in Hilsenhoff (1987). In reality, most spring samples (78%) were collected in March, well before degree-day accumulation limits were approached. The summer index period was between June 1 and September 30 (Kazyak 1994).

2.3.1 Data Collection and Measurement

Field sampling followed procedures specified in the MBSS sampling manual (e.g., Kazyak 1996). A summary of the variables measured and the field and laboratory methods used to conduct the sampling follows.

2.3.1.1 Water Chemistry

During the spring index period, water samples were collected at each site for analysis of pH, acid neutralizing capacity (ANC), conductivity, sulfate, nitrate-nitrogen, and dissolved organic carbon (DOC). These variables describe basic water quality conditions with an emphasis on factors related to acidic deposition.

Grab samples were collected in one-liter bottles for analysis of all analytes except pH. Water samples for pH were collected with 60 ml syringes, which allowed purging of air bubbles to minimize changes in carbon dioxide content (EPA 1987). Samples were stored on wet ice and shipped on wet ice to the analytical laboratory within 48 hours. Laboratory analyses were carried out by the University of Maryland's Appalachian Laboratory in Frostburg.

Chemical analysis of water samples followed standard methods described in EPA's Handbook of Methods for Acid Deposition Studies (EPA 1987). These methods are summarized in Table 2-2. EPA protocols were followed, except that ANC sample volume was reduced to 40 ml to ease sample handling. Routine daily quality control (QC) checks included processing duplicate, blank, and calibration samples according to EPA guidelines for each analyte. Field duplicates were taken at 5% of all sites. Routine QC checks helped to identify and correct errors in sampling routines or instrumentation at the earliest possible stage.

During the summer index period, *in situ* measurements of dissolved oxygen (DO), pH, temperature, and conductivity were collected at each site to further characterize existing water quality conditions that might influence biological communities. Measurements were made at an undisturbed section of the segment, usually in the middle of the stream channel, using electrode probes. Instruments were calibrated daily and calibration logbooks were maintained to document instrument performance.

2.3.1.2 Benthic Macroinvertebrates

Benthic macroinvertebrates were collected to provide a qualitative description of the community composition at each sampling site (Kazyak 1996). Sampling was conducted during the spring index period. Benthic community data were collected for the purpose of calculating biological metrics, such as those described in EPA's Rapid Bioassessment Protocols (Plafkin et al. 1989), and use as an indicator of biological integrity for Maryland streams.

At each segment, a 600 micron mesh "D" net was used to collect organisms from habitats likely to support the greatest taxonomic diversity. A riffle area was preferred, but other habitats were also sampled using a variety of techniques including kicking, jabbing, and gently rubbing hard surfaces by hand to dislodge organisms. If available, other habitat types were sampled, including rootwads, woody debris, leaf packs, macrophytes, and undercut banks. Each jab covered one square foot, and a total of approximately 2.0 m^2 (20 square feet) of combined substrates was sampled and preserved in 70% ethanol. In the laboratory, the preserved sample was transferred to a gridded pan and organisms were picked from randomly selected grid cells until the cell that contained the 100th individual (if possible) was completely picked. Some samples had fewer than 100 individuals. The benthic macroinvertebrates were identified to genus, or lowest practicable taxon, in the laboratory.

2.3.1.3 Fish

Fish were sampled during the summer index period using double-pass electrofishing within 75-meter stream segments. Block nets were placed at each end of the segment and direct current backpack electrofishing units were used to sample the entire segment. An attempt was made to thoroughly fish each segment, sampling the entire stream segment. A consistent effort was applied over the two passes. This sampling approach allowed calculation of several metrics useful in calculating a biological index and produced estimates of fish species abundance.

Table 2-2. Analytical methods used for water chemistry samples collected during the spring index period. See EPA (1987) for details				
Analyte (units)	**Method**	**Instrument**	**Detection Limit**	**Holding Time (days)**
pH (standard units)	EPA Sec. 19.0	Closed system using Orion 611 pH meter equipped with Orion 08104 Ross combination electrode and Hellman chamber	0.01	7
Specific Conductance (μmho/cm)	EPA 120.1	YSI 32 equipped with 3403 conductivity cell (1.0 cm/sec cell constant)	NA	14
Acid Neutralizing Capacity (μeq/l)	EPA Sec. 5.0 modified	Titration (modified Gran analysis) using Orion 611 pH meter	NA	14
Dissolved Organic Carbon (mg/l)	EPA 415.1	Doorman DC-80 carbon analyzer	1.0	14
Sulfate (mg/l)	EPA 300.0	Danaus 2001i ion chromatography (with upgrade)	0.206	14
Nitrate Nitrogen (mg/l)	EPA 300.0	Danaus 2001i ion chromatography (with upgrade)	0.013	14
NA = Not Applicable				

In small streams, a single electrofishing unit was used. In larger streams, two to five units were employed to effectively sample the site. Captured fish were identified to species, counted, weighed, and released. Any individuals that could not be identified to species were retained for laboratory confirmation. For each pass, all individuals of each gamefish species (defined as trout, bass, walleye, pike, chain pickerel, and striped bass) were measured for total length and examined for visible external pathologies or anomalies. For nongame species, up to 100 fish of each species (from both passes) were examined for visible external pathologies or anomalies. For each pass, all non-game species were weighed together for an aggregate biomass measurement; gamefish were also weighed in aggregate to the nearest 10 g.

Electrofishing was also conducted at supplemental, non-randomly selected sites during the summer. The presence of each species of fish was recorded for these segments to provide additional qualitative information on fish distributions. Sampling effort at most supplemental sites was based on doubling the elapsed time since the last species was recorded or a minimum of 600 seconds of electrofishing effort.

After processing the fish collection in the field, voucher specimens were retained for each species not previously collected in the drainage basin. In addition, all individuals which could not be positively identified in the field were retained. The remaining fish were released. All voucher specimens and fish retained for positive identification in the laboratory were examined and verified by the MBSS Quality Assurance Officer or ichthyologists at Frostburg State University, Frostburg, Maryland or the Smithsonian Institution, Washington, DC.

2.3.1.4 Amphibians and Reptiles

At each sample segment, amphibians and reptiles were identified and the presence of observed species was recorded during the summer index period. A search of the riparian area was conducted within 5 meters of the stream on both sides of the 75-meter segment. Any amphibians and reptiles collected during the electrofishing of the stream segment were also included in the species list. Individuals were identified to species when possible. Voucher specimens and individuals not positively identifiable in the field were retained for examination in the laboratory and confirmation by herpetologists at the Smithsonian Institution, Washington, DC, and/or Towson University, Towson, Maryland.

2.3.1.5 Mussels

During the summer index period, freshwater mussels were sampled qualitatively by examining each 75-meter stream segment for their presence. Mussels were identified to species, their presence recorded, and individuals released. Species not positively identifiable in the field were retained for confirmation by U.S. Geological Survey (USGS) Biological Resources Division staff.

2.3.1.6 Aquatic Vegetation

During the summer index period, aquatic vegetation was sampled qualitatively by examining each 75-meter stream segment for the presence of aquatic plants. Plants were identified to species and their (if possible) presence recorded for each site. While the primary objective was to document the presence of submerged aquatic vegetation (SAV), emergent vegetation was also recorded when encountered. Species not positively identifiable in the field were retained for examination in the laboratory and confirmation by DNR's staff expert on SAV. Due to the difficulty in long-term preservation, no permanent vouchers of aquatic vegetation were retained.

2.3.1.7 Physical Habitat

Habitat assessments were conducted at all stream segments as a means of assessing the importance of physical habitat to the biological integrity and fishability of freshwater streams in Maryland. Procedures for habitat assessments (Kazyak 1996) were derived from two currently used methodologies: EPA's Rapid Bioassessment Protocols (RBPs) (Plafkin et al. 1989), as modified by Barbour and Stribling (1991), and the Ohio EPA's Qualitative Habitat Evaluation Index (QHEI) (Ohio EPA 1987, Rankin 1989). Guidelines for qualitative habitat assessment scoring are listed in Table 2-3. A number of characteristics (instream habitat, epifaunal substrate, velocity/depth diversity, pool/glide/eddy quality, riffle/run quality, channel alteration, bank stability, embeddedness, channel flow status, and shading) were assessed qualitatively, based on visual observations within each 75-meter sample segment. Riparian zone vegetation width was estimated to the nearest meter, up to 50 meters from the stream. Additional observations of the surrounding area were used to assign ratings for aesthetic value (based on visible signs of human refuse at a site) and remoteness (based on distance from the nearest road, accessibility, and evidence of human activity). Also recorded were the presence or absence of various stream features including substrate types, various morphological characteristics, beaver ponds, point sources, and stream channelization. Local land uses visible from the stream segment and riparian vegetation type were also noted.

Several additional physical characteristics were measured quantitatively to further characterize the habitat for each segment (see Kazyak 1996 for details). Quantitative measurements of the segment included maximum depth, stream gradient, velocity, thalweg depth, number of functional rootwads, number of functional large woody debris, wetted width, sinuosity, and overbank flood height. A velocity/depth profile was measured or other data were collected to enable calculation of discharge.

Recognizing that water temperature is an important factor affecting stream condition (but one that varies daily and seasonally), the Survey deployed temperature loggers at 220 sites in five basins during the sample year 1997. The basins sampled were: the Choptank, Susquehanna, Potomac Washington Metro, Patuxent, and Pocomoke basins. Onset Computer Corporation Optic Stowaway model temperature loggers were anchored in each sample site during the summer index period. They recorded the water temperature every 15 minutes from June 15 until mid-September.

2.3.2 Data Management

All crews used standardized pre-printed data forms developed for the Survey to ensure that all data for each sampling segment were recorded and standard units of measure were used (Kazyak 1996). Using standard data forms facilitated data entry and minimized transcription error. The field crew leader and a second reviewer checked all data sheets for completeness and legibility before leaving each sampling location. Original data sheets were sent to the Data Management Officer for further review and data entry, while copies were retained by the field crews.

A custom database application, in which the input module was designed to match each of the field data sheets, was used for data entry. Data were independently entered into two databases and compared using a computer program as a quality-control procedure. Differences between the two databases were resolved from original data sheets or through discussions with field crew leaders.

Table 2-3. Guidelines for qualitative habitat assessment (Kazyak 1996)

MBSS Habitat Assessment Guidance Sheet				
Habitat Parameter	**Optimal 16-20**	**Sub-Optimal 11-15**	**Marginal 6-10**	**Poor 0-5**
1. Instream Habitat[(a)]	Greater than 50% mix of a variety of cobble, boulder, submerged logs, undercut banks, snags, rootwads, aquatic plants, or other stable habitat	30-50% mix of stable habitat. Adequate habitat	10-30% mix of stable habitat. Habitat availability less than desirable	Less than 10% stable habitat. Lack of habitat is obvious
2. Epifaunal Substrate[(b)]	Preferred substrate abundant, stable, and at full colonization potential (riffles well developed and dominated by cobble; and/or woody debris prevalent, not new, and not transient)	Abund. of cobble with gravel &/or boulders common; or woody debris, aquatic veg., undercut banks, or other productive surfaces common but not prevalent /suited for full colonization	Large boulders and/or bedrock prevalent; cobble, woody debris, or other preferred surfaces uncommon	Stable substrate lacking; or particles are over 75% surrounded by fine sediment or flocculent material
3. Velocity/Depth Diversity[(c)]	Slow (<0.3 m/s), deep (>0.5 m); slow, shallow (<0.5 m); fast (>0.3 m/s), deep; fast, shallow habitats all present	Only 3 of the 4 habitat categories present	Only 2 of the 4 habitat categories present	Dominated by 1 velocity/depth category (usually pools)
4. Pool/Glide/Eddy Quality[(d)]	>50% pool/glide/eddy habitat; both deep (>.5 m)/shallows (<.2 m) present; complex cover/&/or depth >1.5 m	10-50% pool/glide/eddy habitat, with deep (>0.5 m) areas present; or >50% slow water with little cover	<10% pool/glide/eddy habitat, with shallows (<0.2 m) prevalent; slow water areas with little cover	Pool/glide/eddy habitat minimal, with max depth <0.2 m, or absent completely
5. Riffle/Run Quality[(e)]	Riffle/run depth generally >10 cm, with maximum depth greater than 50 cm (maximum score); substrate stable (e.g. cobble, boulder) & variety of current velocities	Riffle/run depth generally 5-10 cm, variety of current velocities	Riffle/run depth generally 1-5 cm; primarily a single current velocity	Riffle/run depth < 1 cm; or riffle/run substrates concreted
6. Channel Alteration[(f)]	Little or no enlargement of islands or point bars; no evidence of channel straightening or dredging; 0-10% of stream banks artificially armored or lined	Bar formation, mostly from coarse gravel; and/or 10-40% of stream banks artificially armored or obviously channelized	Recent but moderate deposition of gravel and coarse sand on bars; and/or embankments on both banks; and/or 40-80% of banks artificially armored; or channel lined in concrete	Heavy deposits of fine material, extensive bar development; OR recent channelization or dredging evident; or over 80% of banks artificially armored
7. Bank Stability[(g)]	Upper bank stable, 0-10% of banks with erosional scars and little potential for future problems	Moderately stable. 10-30% of banks with erosional scars, mostly healed over. Slight potential in extreme floods	Moderately unstable. 30-60% of banks with erosional scars and high erosion potential during extreme high flow	Unstable. Many eroded areas. "Raw" areas frequent along straight sections and bends. Side slopes >60° common
8. Embeddedness[(h)]	Percentage that gravel, cobble, and boulder particles are surrounded by line sediment or flocculent material.			
9. Channel Flow Status[(i)]	Percentage that water fills available channel			
10. Shading[(j)]	Percentage of segment that is shaded (duration is considered in scoring). 0% = fully exposed to sunlight all day in summer; 100% = fully and densely shaded all day in summer			
11. Riparian Buffer[(k)]	Minimum width of vegetated buffer in meters; 50 meters maximum; see back of Habitat Assessment Data Sheet for buffer type and land cover immediately adjacent to buffer			

Table 2-3. Continued

Habitat Parameter	Optimal (16-20)	Sub-Optimal (11-15)	Marginal (6-10)	Poor (0-5)
12. Aesthetic Rating[l]	Little or no evidence of human refuse present; vegetation visible from stream essentially in a natural state	Human refuse present in minor amounts; and/or channelization present but not readily apparent; and/or minor disturbance of riparian vegetation	Refuse present in moderate amounts; and/or channelization readily apparent; and/or moderate disturbance of riparian vegetation	Human refuse abundant and un-sightly: and/or extensive unnatural channelization; and/or nearly complete lack of vegetation
13. Remoteness[m]	Stream segment more than 1/4 mile from nearest road; access difficult and little or no evidence of human activity	Stream segment within 1/4 of but not immediately accessible to roadside access by trail; site with moderately wild character	Stream within 1/4 mile of roadside and accessible by trail; anthropogenic activities readily evident	Segment immediately adjacent to roadside access; visual , olfactory, and/or auditory displeasure experienced

a) **Instream Habitat** Rated based on perceived value of habitat to the fish community. Within each category, higher scores should be assigned to sites with a variety of habitat types and particle sizes. In addition, higher scores should be assigned to sites with a high degree of hypsographic complexity (uneven bottom). In streams where ferric hydroxide is present, instream habitat scores are not lowered unless the precipitate has changed the gross physical nature of the substrate. In streams where substrate types are favorable but flows are so low that fish are essentially precluded from using the habitat, low scores are assigned. If none of the habitat within a segment is useable by fish, a score of zero is assigned.

b) **Epifaunal Substrate** Rated based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. Because they inhibit colonization, flocculent materials or fine sediments surrounding otherwise good substrates are assigned low scores. Scores are also reduced when substrates are less stable.

c) **Velocity/Depth Diversity** Rated based on the variety of velocity/depth regimes present at a site (slow-shallow, slow-deep, fast-shallow, and fast-deep). As with embeddedness, this metric may result in lower scores in low-gradient streams but will provide a statewide information on the physical habitat found in Maryland streams.

d) **Pool/Glide/Eddy Quality** Rated based on the variety and spatial complexity of slow- or still-water habitat within the sample segment. It should be noted that even in high-gradient segments, functionally important slow-water habitat may exist in the form of larger eddies. Within a category, higher scores are assigned to segments which have undercut banks, woody debris or other types of cover for fish.

e) **Riffle/Run Quality** Rated based on the depth, complexity, and functional importance of riffle/run habitat in the segment, with highest scores assigned to segments dominated by deeper riffle/run areas, stable substrates, and a variety of current velocities.

f) **Channel Alteration** Is a measure of large-scale changes in the shape of the stream channel. Channel alteration includes: concrete channels, artificial embankments, obvious straightening of the natural channel, rip-rap, or other structures, as well as recent bar development. Ratings for this metric are based on the presence of artificial structures as well as the existence, extent, and coarseness of point bars, side bars, and mid-channel bars which indicate the degree of flow fluctuations and substrate stability. Evidence of channelization may sometimes be seen in the form of berms which parallel the stream channel.

g) **Bank Stability** Rated based on the presence/absence of riparian vegetation and other stabilizing bank materials such as boulders and rootwads, and frequency/size of erosional areas. Sites with steep slopes are not penalized if banks are composed solely of stable materials.

h) **Embeddedness** Rated as a percentage based on the fraction of surface area of larger particles that is surrounded by fine sediments on the stream bottom. In low gradient streams with substantial natural deposition, the correlation between embeddedness and fishability or ecological health may be weak or non-existent, but this metric is rated in all streams to provide similar information from all sites statewide.

i) **Channel Flow Status** Rated based on the percentage of the stream channel that has water, with subtractions made for exposed substrates and islands.

j) **Shading** Rated based on estimates of the degree and duration of shading at a site during summer, including any effects of shading caused by landforms.

k) **Riparian Buffer Zone** Based on the size and type of the vegetated riparian buffer zone at the site. Cultivated fields for agriculture which have bare soil to any extent are not considered as riparian buffers. At sites where the buffer width is variable or direct delivery of storm runoff or sediment to the stream is evident or highly likely, the smallest buffer in the segment. (e.g., 0 if parking lot runoff enters directly to the stream) is measured and recorded even though some of the segment may have a well developed buffer. In cases where the riparian zone on one side of the stream slopes away from the stream and there is no direct point of entry for runoff, the buffer on the other side of the stream should be measured and recorded and a comment made in comments section of the data sheet.

l) **Aesthetic Rating** Rated based on the visual appeal of the site and presence/absence of human refuse, with highest scores assigned to stream segments with no human refuse and visually outstanding character.

m) **Remoteness** Rated based on the absence of detectable human activity and difficulty in accessing the segment.

2.3.3 QA/QC for Field Sampling

A Quality Assurance Officer (QAO) experienced in all aspects of the Survey was appointed to administer the quality assurance program. Specific quality assurance activities administered by the QAO included preparing a field manual of standard sampling protocols, designing standard forms for recording field data, conducting field crew training and proficiency examinations, conducting field and laboratory audits, making independent habitat assessments, identifying taxa, reviewing all reports, and reporting errors.

To ensure consistent implementation of sampling procedures and a high level of technical competency, experienced field biologists were assigned to each crew and all field personnel completed program training before participating in field sampling. Training topics included MBSS program orientation, stream segment location using global positioning system (GPS) equipment, sampling protocols, operation and maintenance of sampling equipment, data transcription, quality assurance/quality control, and safety. The spring field crew received additional training in sampling protocols for water quality and benthic macroinvertebrates. The summer field crews received additional training in habitat assessment methods, taxonomy, and *in situ* water chemistry assessment.

Training included classroom, laboratory, and field activities. Instructors emphasized the objectives of the Survey and the importance of strict adherence to the sampling protocols. The QAO conducted proficiency examinations to evaluate the effectiveness of the training program and ensure that the participants had detailed knowledge of the sampling protocols. Members of the spring sampling crew were required to demonstrate proficiency in techniques for collecting samples for water chemistry and benthic macroinvertebrates. At least one member of the summer sampling crew was required to pass a comprehensive fish taxonomy examination. Each crew had to demonstrate proficiency in locating pre-selected stream segments using the GPS receiver and determining if the segment was acceptable for sampling. Comprehensive "dry runs" were conducted to simulate actual field conditions and evaluate classroom instruction.

Field audits were conducted by the QAO during the field sampling to assess the adequacy of training, adherence to sampling protocols, and accuracy of data transcription. The audits included evaluation of the preparation and planning prior to field sampling, stream segment location using GPS equipment and assessment of acceptability for sampling, adherence to sampling protocols, data transcription, and equipment maintenance and calibration. The QAO made an independent assessment of habitat at all segments where field audits were done, approximately 10% of the total number of sites.

2.4 STATISTICAL METHODS

Basins sampled in the MBSS were selected in a probabilistic manner using the lattice design described in section 2.1, so that the stratified random sample of basins could be used for developing both statewide and basin-specific estimates. Within each basin, stream data were collected from a stratified random sample of stream segments as described in section 2.1. The study design allowed for estimation of parameters of interest and biological characteristics, as described below, including mean values and percentage of stream miles exhibiting a characteristic of interest. Because samples were independent and identically distributed within strata, the design also allowed for regression and correlation analyses.

2.4.1 Estimates Based on Stratified Random Sampling (Statewide or Basinwide Estimates)

The observations (y) for segments in the stratified random sample are used to estimate the parameters of interest (e.g., totals, means, proportions, percentiles). The mean for all stream segments in a basin (across stream order) can be estimated as a weighted mean of the sample values. The estimator for the stratified mean of y (e.g., average number of fish per stream segment) is

$$\bar{y}_{st} = \sum W_h \bar{y}_h \qquad \textbf{(1)}$$

where $\mathbf{W_h}$ is the number of stream miles of order **h** relative to the total number of stream miles in the basin and $\mathbf{y_h}$ is the mean of y within stream order **h** (Cochran 1977). For example, if there were 348.5 miles of first order streams in the Gunpowder basin out of a total 466.1 first-, second-, and third-order stream miles, $\mathbf{W_1}$ would equal 348.5/466.1 or 0.748.

The estimator for the variance of the stratified mean of y (across stream order) is

$$Var(\bar{y}_{st}) = \sum W_h^2 \frac{s_h^2}{n_h} \qquad \textbf{(2)}$$

and

$$s_h^2 = \sum (y_{h,i} - \bar{y}_h)^2 / (n_h - 1) \qquad \textbf{(3)}$$

is the sample estimate of the variance in the **h**-th stream order, where $\mathbf{y_{hi}}$ is the value of *y* for segment **i** in stratum **h** (Cochran 1977), and $\mathbf{n_h}$ is the number of samples in the **h**-th stream order.

The above methods were also used to estimate proportions of all stream miles in a basin falling in a given category (e.g., percentage of stream miles in the Upper Potomac basin with ANC < 0 μeq/l) by introducing an indicator variable **I** that takes the value 1 if the observation falls in the specified category, and 0 otherwise. The stratified mean (and standard error) of this indicator variable provides an estimate of the proportion of the population that falls in the category of interest. For stratified random sampling, confidence intervals were derived from the standard errors of the stratified estimates, given that the sample sizes were large enough for the central limit theorem to apply.

2.4.2 Estimates Based on Simple Random Sampling (Within One Stream Order Within a Basin)

Within stream order **h** in a basin, a simple random sample $\mathbf{n_h}$ of segments was selected. Estimates of means (e.g., mean number of fish per segment) are based on the ordinary sample means. If 100% capture efficiency is assumed, the total number or biomass of fish by species is obtained by extrapolating the mean number of fish per segment (combined total from two passes) to the total stream length. In section 2.5, a method is presented for correcting for capture efficiency based on double-pass electrofishing (for details, see Heimbuch et al. 1997).

For simple random sampling, as was used within a stream order within a basin, exact confidence intervals for proportions (or percentages) can be obtained from the binomial distribution. Assume that of the $\mathbf{n_h}$ segments, the number of samples falling in a certain class is $\mathbf{B_h}$ = sum $\mathbf{I_h}$, where the indicator variable $\mathbf{I_h}$ takes the value 1 if the observation falls in the specified category (e.g., ANC < 0), and 0 otherwise. An unbiased estimator of the proportion of segments that falls in the class for the entire stream order in the basin is simply

$$p_h = B_h/n_h,$$

with exact upper and lower confidence limits (Hollander and Wolfe 1973):

$$P_L^{\alpha}(n,\ B) = \frac{B}{B + (n - B + 1)\ f_{\alpha/2,2(n-B+1),2B}} \qquad \textbf{(4)}$$

$$P_U^{\alpha}(n,\ B) = 1 - P_L^{\alpha}(n,\ n - B) \qquad \textbf{(5)}$$

where **L** and **U** signify the lower and upper confidence limits, **B** is the number of successes in the **n** Bernoulli trials and $\mathbf{f_{\gamma,n1,n2}}$ is the upper γth percentile for **F** distribution with $\mathbf{n_1}$ degrees of freedom in the numerator and $\mathbf{n_2}$ degrees of freedom in the denominator.

2.4.3 Estimation of Biological Characteristics

To estimate biological characteristics for a fish population in a basin (e.g., the size composition of the population of brook trout), the proportions **p** of fish falling into size categories is estimated. Since fish are caught in clusters, statistical methods based on the assumption that samples of individuals are independent, identically distributed, such as binomial or multinomial distributions for estimating proportions, are not valid (Brier 1980, Fay 1985, Roland Thomas and Rao 1987, Skinner et al. 1989). The sampling unit in the electrofishing survey is the individual stream segment, and not the individual fish (Pennington and Vølstad 1994). Therefore, a ratio estimator is used for estimating the proportion of fish within a specific size group (Cochran 1977). The same method is used to estimate the proportion of fish with a specific type of anomaly.

For a species of interest, let $\mathbf{a_{i,h}}$ be the number of fish caught at the **i**-th segment in stream order **h** falling in class **C** (e.g., number of smallmouth bass above legal size), and let $\mathbf{p_{ih}=a_{ih}/y_{ih}}$ where $\mathbf{y_{ih}}$ is the total number of fish caught. A sample estimate of the proportion $\mathbf{p_h}$, falling in class **C** in the population in stratum **h** (Cochran 1977) is

$$p_h = \frac{\sum_{i=1}^{n_h} a_{i,h}}{\sum_{i=1}^{n_h} y_{i,h}} \qquad \textbf{(6)}$$

and an estimate of the variance of $\mathbf{p_h}$ is

$$\mathrm{var}(p_h) = \frac{\sum a_{i,h}^2 - 2p_h \sum a_{i,h} y_{i,h} + p_h^2 \sum y_{i,h}^2}{n_h \overline{y}^2 (n_h - 1)} \qquad \textbf{(7)}$$

where summation is over all segments ($\mathbf{n_h}$) in stratum **h**.

The ratio estimator is biased, but the bias is small for large sample sizes. For small sample sizes (e.g., less than 30), a jackknife estimator would be more efficient (Efron and Gong 1983, Wu and Deng 1983, Pennington and Vølstad 1994). For estimating the proportion falling in class C of the entire population of fish in a basin (i.e., across all stream orders), the stratification of stations needs to be taken into account. The combined ratio estimator (Cochran 1977) was used to estimate proportions of the overall population ($\mathbf{p_{st}}$) in class **C**:

$$p_{st} = \frac{\sum w_h a_h}{\sum w_h y_h} \qquad \textbf{(8)}$$

where for the **h-**th stratum $\mathbf{w_h}$ is the proportion of the stream length in the stratum, $\mathbf{a_h}$ is the total number of fish in class **C** caught in the stratum, and $\mathbf{y_h}$ is the total number of fish (all classes) caught in the stratum. The variance of $\mathbf{p_{st}}$ is estimated by jackknifing (Saerndal et al. 1992).

2.5 CAPTURE EFFICIENCY ADJUSTMENT FOR FISH POPULATION ESTIMATES

Estimates of fish density (number of individuals per stream mile) and total abundance (number of individuals per basin) were corrected for capture efficiency using an analytical technique developed with the 1995 MBSS data. This method used electrofishing catch data to estimate actual density and population size based on the rate of decline in catch per unit effort over the two passes. Typically, it is difficult to make estimates of capture efficiency with a small number of passes from a single site because of the likelihood, for some fish species, of collecting on the second pass an equal or greater number of fish than on the first pass. To address this problem, this new method pooled samples over multiple stream segments within the same stream order and basin. Using a modified Seber-LeCren estimator (Seber 1982, Seber and LeCren 1967), this technique analytically corrected for bias introduced by variable probability of capture and minimized bias typically resulting from small sample size. The capture efficiency adjustment method is described fully in Heimbuch et al. (1997) and Roth et al. (1997).

2.6 LANDSCAPE ANALYSIS

Land uses within watersheds upstream of sample sites were derived with a geographic information system (GIS), using Micro Images (MIPS) and PC Arc Info software. Watersheds upstream of each sample site were digitized using topographic lines from digital county topographic maps (1:62,500 scale). Watersheds were digitized in TNT MIPS and exported to PC Arc Info. The watershed file was then intersected with land use/land cover information from the Federal Region III Multi-Resolution Land Characteristics (MRLC) digital data set, Version 2 (MRLC 1996a,b). The MRLC was developed by a federal agency consortium, using data primarily from Landsat 1991-93 Thematic Mapper satellite images at a resolution of 30 x 30 m pixels. The MRLC classifies land cover into 15 categories (Table 2-4). Using GIS, the area within each watershed was calculated as was the percentage of area within each watershed represented by each type of land use. For some analyses, land uses were collapsed to the following six classes: water, urban land, agriculture, forest, wetlands, and barren.

Table 2-4. Land cover classes in the Multi-Resolution Land Characteristics data set for Region III (Version 2, MRLC 1996a, b). Percentages given in class definitions should be viewed as guidelines.

Water

Open Water - all areas of open water, generally with less than 25 percent vegetation or other land cover.

Developed Land

Low Intensity Developed - Land includes areas with a mixture of constructed materials and vegetation or other cover. Constructed materials account for 30-80 percent of the total area. Commonly includes single-family housing areas, such as suburban neighborhoods.

High Intensity Developed - Includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas. Vegetation occupies less than 20 percent of the landscape. Constructed materials account for 80-100 percent of the total area. Examples include apartment complexes, skyscrapers, shopping centers, factories, industrial complexes, airport runways, and interstate highways.

Herbaceous Planted / Cultivated

Hay / Pasture / Grass - Grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops. Also includes golf courses and city parks.

Row Crops - All areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.

Probable Row Crops - Areas of row crop that may be confused with other areas, such as grasslands that were not green during times of spring data acquisition.

Natural Forested Upland

Deciduous Forest - Areas dominated by trees where 75 percent or more of the tree species shed foliage seasonally.

Evergreen Forest - Areas dominated by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.

Mixed Forest - Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.

Wetlands

Woody Wetlands - Areas of forested or shrubland vegetation where the soil or substrate is periodically saturated with or covered with water as defined by Cowardin et al. (1979).

Emergent Herbaceous Wetlands - Non-woody vascular perennial vegetation where the soil or substrate is periodically saturated with or covered with water as defined by Cowardin et al.(1979)

Barren

Quarries / Strip Mines / Gravel Pits - Areas of extractive mining activities with significant surface expression.

Coal Mines - Areas dominated by spectrally dark coal piles and strip mines.

Bare Rock/Sand/Clay - Includes areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, beach, and other accumulations of rock and/or sand without vegetative cover.

Transitional - Areas dynamically changing from one land cover to another, often because of land use activities. Examples include forest lands cleared for timber, and may include areas freshly cleared or in early stages of forest regrowth.

3 ENVIRONMENTAL SETTING

This chapter describes the environmental setting of Maryland streams. Similar to other states in the mid-Atlantic region, Maryland stream environments vary considerably from east to west and from north to south. Within the chapter, important features such as geologic history, climate, physiography, geology and soils, and human influences on the landscape are presented. This information provides a useful context for interpreting the condition of Maryland streams.

3.1 GEOLOGIC HISTORY

Historical changes in the physical environment are a primary factor influencing the diversity and distribution of aquatic species in Maryland streams. The following discussion describes some events in the past that have influenced, and in many cases continue to influence, Maryland stream ecosystems.

3.1.1 Evolution of Drainage Patterns

Chesapeake Bay, the water body into which most Maryland streams drain, has changed dramatically over geologic time. Most streams in the Bay drainage were part of the Susquehanna River tributary network; some areas such as the upper Potomac drained to the west. Approximately 20,000 years ago, glacial activity extended down through New England as far as south-central Pennsylvania. As glacial activity receded, broad-scale landform erosion caused shifts in drainage patterns. Over time, the eastern continental divide shifted considerably westward to its present location between Grantsville and Frostburg, Maryland. As each stream was captured by this shifting continental divide, there were opportunities for interbasin transfers of aquatic species. At present, the species assemblages on both sides of the continental divide overlap considerably, increasing the similarity in community composition between the western and eastern parts of the State.

As a result of glacial and post-glacial landform erosion, there are two major drainages in Maryland today: the Chesapeake Bay which empties into the Atlantic Ocean and the Youghiogheny River, which ultimately drains to the north and to the Mississippi River. All but one of the major river basins in Maryland drain into the Chesapeake Bay (Figure 2-1). Because these basins form natural ecological and aquatic management boundaries, they are the primary reporting units used for the Maryland Biological Stream Survey (MBSS or the Survey).

3.1.2 Climatic Changes

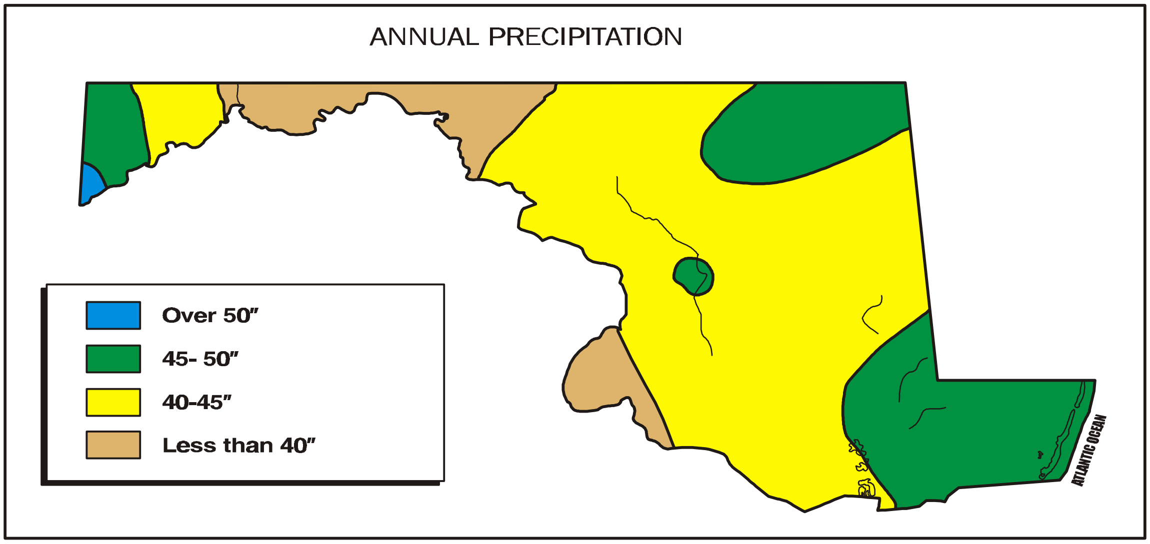
Since the time of the last glaciation, a number of climatic events have occurred that have likely influenced the distribution of aquatic biota. These include extended droughts (dry periods covering several decades) in the 13th and 16th centuries, a uniquely cold and cloudy summer in the 1800s, and several unusually wet periods. The fauna that persists today is well adapted to this relatively dynamic environment.

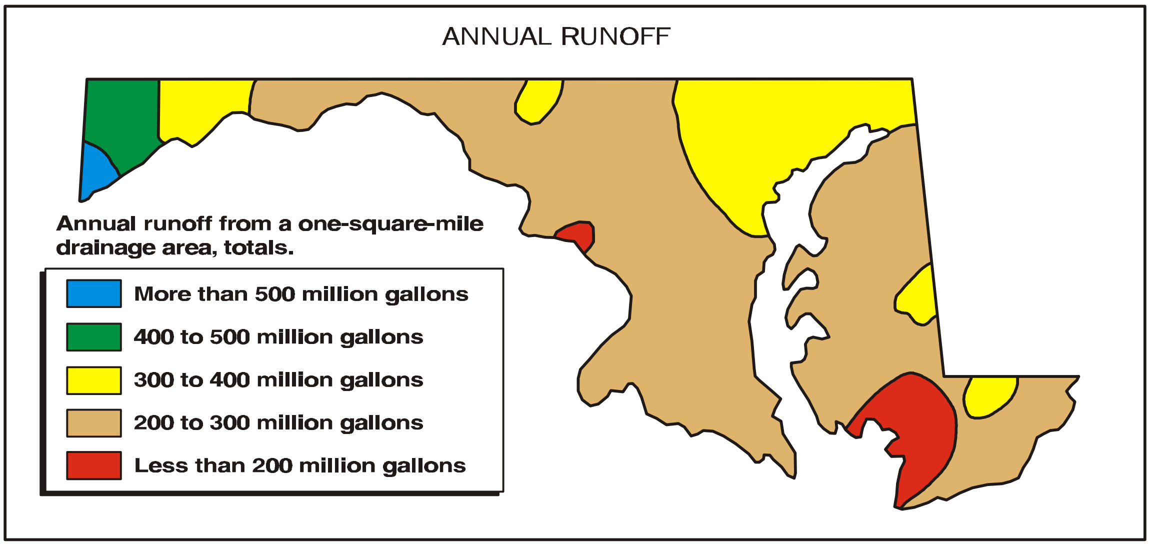
More recently, events such as Hurricane Agnes in 1972 (CRC 1976) and a large snow/rain event in January 1996 have strongly influenced biological, chemical, and physical conditions in Maryland (MDNR, unpublished data) and neighboring Pennsylvania (Hoopes 1975). It is important that MBSS and other data be interpreted in the context of such past abiotic conditions, even if the conditions only persist for weeks or days.

3.2 CLIMATE

3.2.1 Precipitation

Because all flow in Maryland streams ultimately arises from precipitation, it is an important factor in stream condition. In Maryland, annual precipitation varies geographically, averaging between 40 and 50 inches (Figure 3-1). In the western half of the State, the prevailing winds are from the west, typically mixing moisture from the south with colder temperatures from the north. Because of the prevailing winds and mountain ridges, which create a rainshadow effect, rain and snowfall is greater in the west and precipitation tends to be heavier on west-facing slopes. In the eastern half of the State, prevailing winds are also westerly but many storm events are also influenced by moisture from the coast; precipitation patterns reflect that influence. These precipitation patterns have an obvious effect on runoff (Figure 3-1), a primary factor in determining stream characteristics. Because the flow of water (stream discharge) is one of the critical determinants of stream habitat quantity and quality, drier portions of the





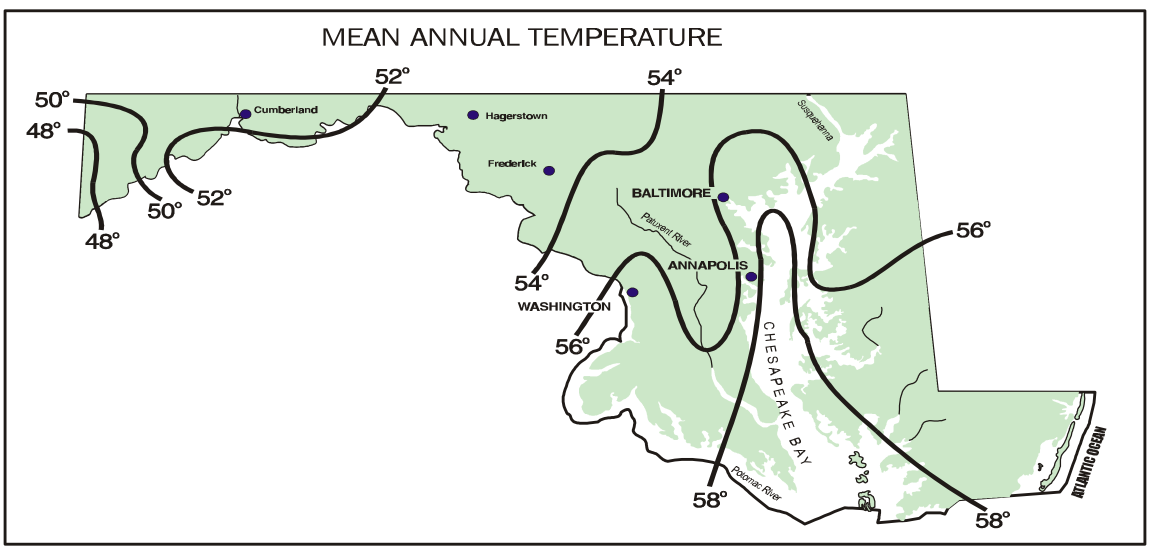


Figure 3-1. Precipitation isobar, annual runoff per square mile of watershed area, and mean annual temperature isobar maps for Maryland (Adapted from Walker 1970)

State should, in general, have less aquatic habitat than areas that are wetter.

3.2.2 Temperature

Mean annual temperatures in Maryland vary between 48° and 58°F, with the coldest areas in far western Maryland and warmest areas near the Chesapeake Bay mainstem (Figure 3-1). Maryland is situated between 37° and 39° north latitude and 75° and 79° west longitude; the State is bounded to the east by the Atlantic Ocean and to the west by the Allegheny mountains. The presence of the Atlantic Ocean on the east and the bays and estuaries that line the Chesapeake Bay to its west create an "oceanic" or "insular" climate on the Eastern Shore. This region of the State experiences milder winters and hotter summers than other regions.

The air temperature regime for each region of Maryland has a direct influence on stream water temperatures, generally favoring warmwater fauna in streams of the eastern and southern part of the State, and coldwater fauna to the north and west. The temperature regime can have a dramatic effect on the diversity of its aquatic assemblages. For example, Atlantic coastal states north of Maryland have fewer, but similar numbers of freshwater fish species, while neighboring Virginia supports more than twice as many native fish species (Jenkins and Burkhead 1993). It appears that Maryland's post-glacial temperature regime may have been slightly colder than the threshold for many of Virginia's fishes. Such differences in temperature requirements demonstrate the need to examine local as well as regional expectations for biological communities. This is particularly important in areas where temperatures are marginally acceptable for coldwater communities, because minor watershed disturbances may dramatically alter these communities.

3.3 PHYSIOGRAPHY

Maryland extends across five Physiographic Provinces which parallel the Atlantic Coast from New England south to the Gulf of Mexico. From east to west, these provinces are: the Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau (Figure 3-2). Each of these provinces has characteristics that strongly influence its constituent streams.

3.3.1 Coastal Plain

The Coastal Plain is the most extensive of the Physiographic Provinces in Maryland. It ranges in elevation from 0 to more than 100 meters above sea level; the Eastern Shore is relatively flat while the Western Shore is typically rolling upland with higher elevations. In comparison with the predominantly slow-moving streams on the Eastern Shore, Western Shore streams have slightly higher stream gradients and more deeply incised stream channels. One major difference between the Coastal Plain and the other Physiographic Provinces in Maryland is the response of streams to organic enrichment. Because of the lower gradient and naturally limited capacity to mechanically aerate the water and replace oxygen lost via biochemical oxygen demand (BOD), streams in the Coastal Plain more often tend to become more overenriched than elsewhere in the State.

3.3.2 Fall Line

The western boundary of the Coastal Plain is the "Fall Line", a sinuous, rather poorly defined "line" characterized by the presence of rapids and waterfalls that mark the beginning of the Piedmont Province. One major waterfall and natural migration barrier to many aquatic species is Great Falls on the Potomac River. The drop in elevation at Great Falls is approximately 10-15 meters, a height that most fish cannot climb except during periods of extreme flooding.

The coincidence of Coastal Plain and Piedmont habitats in the vicinity of the Fall Line tends to result in a mixing of aquatic biota. This mixing typically results in a higher diversity of biota in the transition zone than in upstream or downstream communities. This effect should be considered when interpreting data for the Fall Line region.

3.3.3 Piedmont

The Piedmont Province comprises 29 percent of the land area of the State and extends from its eastern limit at the Fall Line to the slopes of Catoctin Mountain, where it borders the Blue Ridge Province. The Piedmont is characterized by rolling terrain and rather deeply incised stream valleys. Streams in this province generally have moderate slopes controlled by bedrock outcrops; however

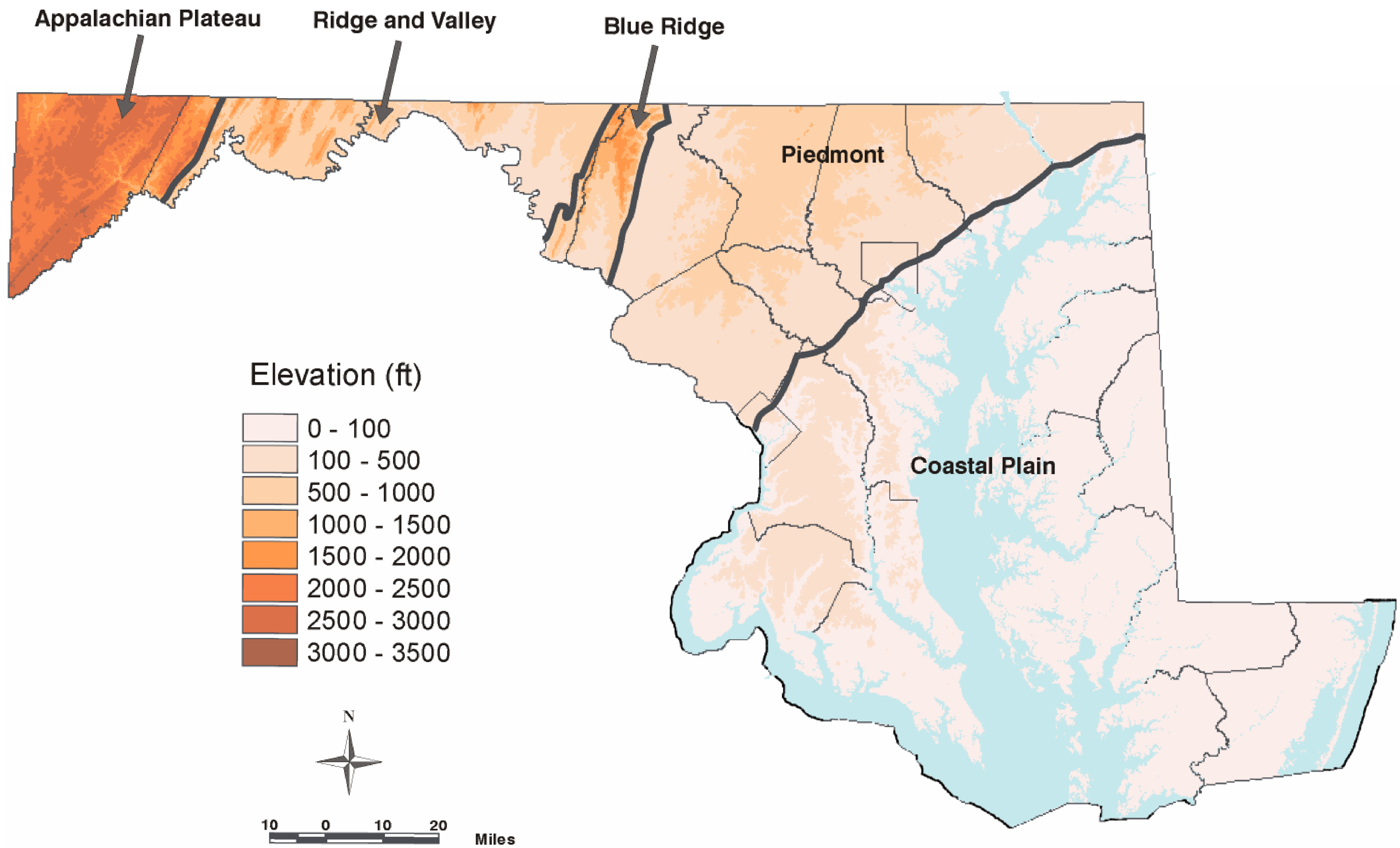


Figure 3-2. Surface elevation map of Maryland (Adapted from MGS 1996)

steeply sloped areas and waterfalls are not uncommon. The variety of rock types, differences in resistence to erosion, and the inherent complexity of physical structure provide this region with a highly diverse topography over elevations from 30 to 300 meters. Like the Coastal Plain, the Piedmont is subdivided into an eastern and western region, defined by streams flowing directly into the Chesapeake Bay and those that flow into the Potomac River, respectively.

3.3.4 Blue Ridge

The Blue Ridge Province makes up approximately 5 percent of the area of the State and extends from Catoctin Mountain to South Mountain, with a broad valley floor flanked by the steeper slopes of Catoctin and South Mountains. Elevations in the Blue Ridge range from approximately 30 to 450 meters; stream gradients range from steep on the mountain slopes to moderate in the valleys.

3.3.5 Valley and Ridge

The Valley and Ridge Province is located between South Mountain and Dans Mountain in western Allegany County. It comprises about 12 percent of the State and includes the Great Valley in the east and the Western Ridges in the west. The Great Valley is a broad lowland that averages 150 to 180 meters in elevation, rising gradually from the Potomac River toward the Pennsylvania border. The Western Ridges consist of numerous northeasterly aligned ridges. Streams within the valleys are moderately sloped and sinuous, while streams that drain the ridges are often steeply sloped. In total the range in elevation in this province extends from 60 to 600 meters.

3.3.6 Appalachian Plateau

The Appalachian Plateau is a broad upland region that extends from Dans Mountain in western Allegany County through the Maryland-West Virginia border. Elevation in the Appalachian Plateau generally ranges from 600 to over 900 meters; stream gradients range from steep along ridges to gentle in some valleys.

3.4 GEOLOGY AND SOILS

3.4.1 Geology

Geology plays a key role in determining the water chemistry, flow characteristics, and physical structure of Maryland streams. Using the lithogeochemical classification system developed by the USGS (Peper et al. 1999), the rock types found in Maryland fall into one of four classes: carbonate, mafic, resistate, and carbonaceous-sulfidic (Figure 3- 3). Each of these classes influences streams in different ways.

Carbonate rocks are found in narrow bands in western Maryland, occur extensively in central Maryland, and are absent from the Coastal Plain. These rocks provide abundant calcium which tends to increase biological productivity and buffers the effects of acidity from sources such as acidic deposition. Streams flowing through carbonate rock formations tend to be well-oxygenated and may have high nitrate levels in agricultural areas. Groundwater in carbonate rocks occupies channels and cavities that are usually small, but may be very large. Movement of groundwater is usually rapid and springs are common and frequently large. The presence of springs in a watershed tends to counter the effects of droughts and spates because they create refugia with relatively constant flows.

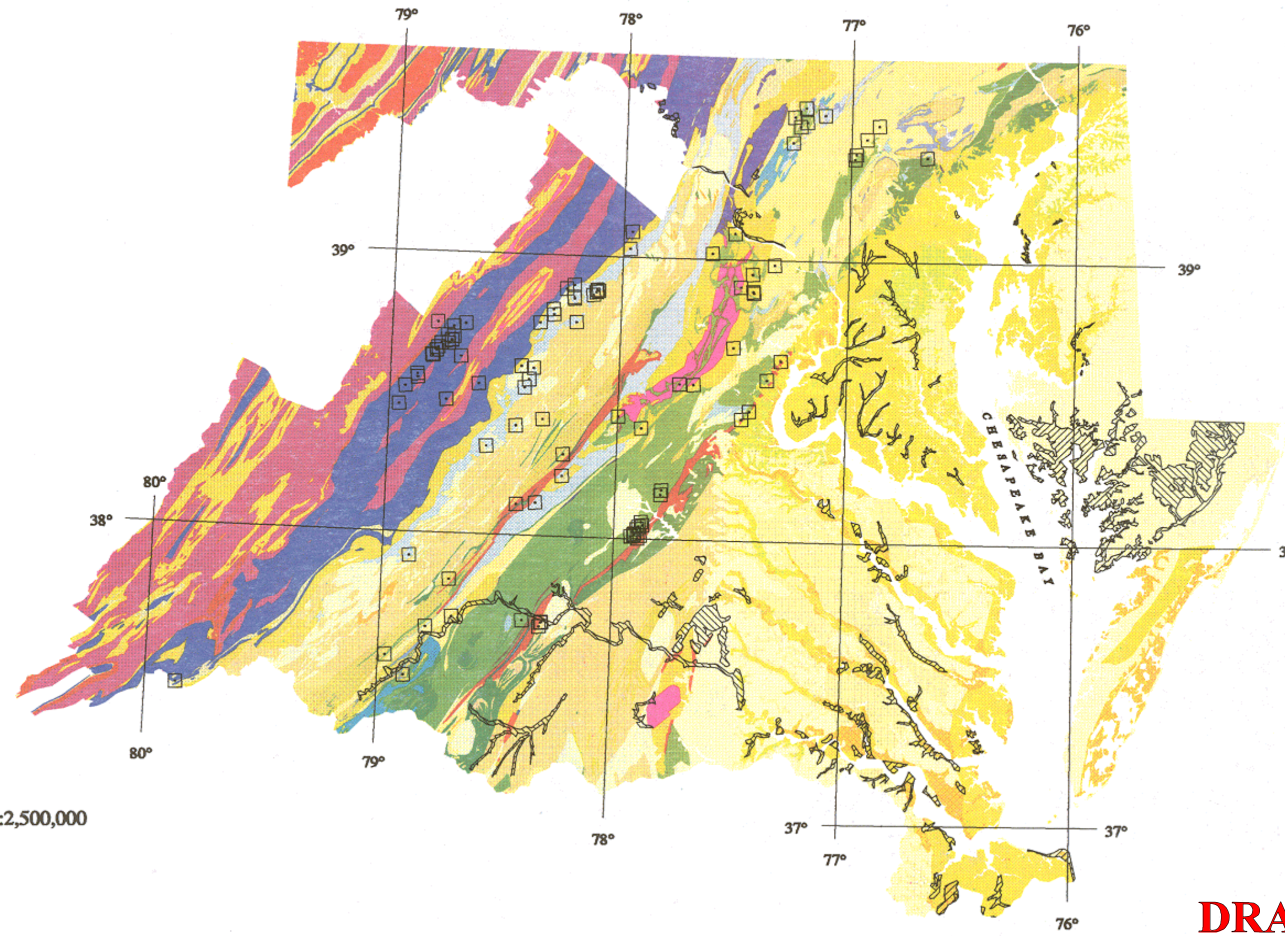
Mafic rocks, which are found along the Fall Line, several isolated areas of the Piedmont, and portions of the northern Coastal Plain, also provide some calcium buffering capacity. Streams flowing through mafic rock formations tend to be neutral to slightly acidic and well-oxygenated, with substrates sub-oxic to reducing in places. Groundwater in mafic rocks occupies small cracks and fissures. Groundwater movement is slow and springs are rare and usually small.

Resistate rocks are found throughout the State, but are especially prevalent in the Piedmont and dominant in the Coastal Plain, and provide little acid-neutralizing capacity. Streams flowing through resistate rock formations tend to be well-oxygenated, but clay-rich rock and sediment is common. Groundwater in resistate rocks occupies small cracks and fissures, moves slowly, and rarely creates springs which are usually small. In the Coastal Plain, groundwater occupies space between particles and movement is slow to moderately rapid.

Carbonaceous-sulfidic rocks, the predominant rock type in the Ridge and Valley and Appalachian Plateau provinces, are associated with historical bog, marsh, or swamp deposits. Streams flowing through this rock formation are reported to be acidic to neutral, to be abundant in dissolved organic carbon and iron, to possess low nitrate levels, and to often have low DO levels. Groundwater in carbonaceous-sulfidic rocks occupies small cracks and fissures, moves slowly, and rarely creates springs which are usually small.

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
VIRGINIA DIVISION OF MINERAL RESOURCES
AND THE
MARYLAND GEOLOGICAL SURVEY



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DRAFT

PRELIMINARY LITHOGEOCHEMICAL MAP OF NEAR-SURFACE ROCK TYPES IN THE CHESAPEAKE BAY WATERSHED, VIRGINIA AND MARYLAND

By

John D. Peper, Lucy B. McCartan, J. Wright Horton, Jr., and James E. Reddy

Figure 3-3. Lithogeochemistry map of Maryland (USGS 1999)

EXPLANATION OF MAP UNITS

I. SEDIMENTARY ROCKS AND THEIR METAMORPIC EQUIVALENTS

——— Carbonate-rich rocks (acid neutralizing and soluble, forms thin alkaline clay soils)

11: limestone, dolomite, limestone-pebble conglomerate; includes calcareous mudstones

12: marble and some calc-silicate rock

——— Siliciclastic sedimentary rocks (moderately acid-neutralizing (cs) to reducing-acidic (s), bedded and permeable, forms neutral to slightly acid soils)

21cs: calcareous, locally sulfidic, gray mudstone

22: sandstone and interbedded sandstone and conglomerate; minor carbonate cement; may contain mudstone

23s: carbonaceous, graphitic, or sulfidic slate and shale

24s: coal beds and zones containing abundant coal beds

——— Metamorphosed clastic sedimentary rocks; includes some metavolcanic layers (moderately acid-neutralizing (c) to acidic (s), recrystallized and foliated, forms neutral to slightly acid soils)

31s: graphitic and sulfidic slate; includes some metagraywacke

32: pelitic schist and phyllite; locally quartzofeldspathic

32s: sulfidic schist and minor quartzofeldspathic schist

32c: calcareous schist and gneiss

33: metasandstone, quartzite, quartz granofels, and gneiss; locally schistose

34: coarse-grained felsic gneiss locally contains schist and amphibolite; typically enriched in granitic components like unit 61

II. IGNEOUS ROCKS AND THEIR METAMORPHIC EQUIVALENTS

——— Mafic igneous rocks and their metamorphic equivalents (moderately acid-neutralizing, massive, has interlocking grains, forms smectitic clay soils)

41c: greenstone, greenschist facies metabasalt, schistose metamorphosed mafic rocks with dispersed carbonate

41: hornblende-plagioclase amphibolite

42: mafic volcanic rocks mixed with lesser felsic volcanics and clastic rocks; metadiamictite, schist-matrix melange

43: massive, mafic plutonic rocks; includes diorite, gabbro, monzodiorite, diabase, and basalt

——— Ultramafic rocks

50c: metamorphosed ultramafic rocks; includes ultramafic melanges, serpentinite, tremolite-talc schist; includes minor carbonate soils

Figure 3-3. Cont'd

EXPLANATION OF MAP UNITS

——— Felsic igneous rocks and their metamorphic equivalents (forms neutral to moderately acidic, sandy soils)

61: granitoid plutonic rocks; includes granite, quartz monzonite, granodiorite, tonalite, trondhjemite, and equivalent gneiss

61v: fine-grained felsic rocks (volcanic and shallow plutonic); cryptocrystalline to very fine-grained

62: quartz-poor plutonic rocks, includes syenite, quartz-syenite, nepheline syenite, and monzonite

III. UNCONSOLIDATED SEDIMENTS (primary porosity is high)

73: mud and clay (>15% clay and silt size particles)

74: quartz silt, sand, and gravel; weathered residuum from which iron and carbonate have been removed

75: organic-rich deposits, including peat

76: mixtures of 73, 74, 75

——— Iron-rich sediment

77: greensand, silty in places; magnetite and ferroilmenite beach sand; bog iron ore

CARBON-RICH SOILS (From U.S. Department of Agriculture, 1994)

11,000 - 17,199 g/square meter total soil carbon

> 17,199 g/square meter total soil carbon

MINERAL DEPOSIT (From USGS, National Mineral Resource Database)

sulfide deposit

Figure 3-3. Cont'd

3.4.2 Soils

Soils play a key role in the formation and maintenance of stream channels. In areas of high soil erodibility, the effects of watershed disturbance (such as loss of riparian buffers) are usually more pronounced. In Maryland, most soils have high or moderately high erodibility (Figure 3-4). In the western half of the State, erodibility is relatively comparable among watersheds. In contrast, erodibility is highly variable in the eastern portion of the State, potentially producing differences in degradation from the same degree of watershed perturbation.

3.5 HUMAN INFLUENCES

The influence of human activities extends to every stream and watershed in Maryland. Because virtually no pre-European records of Maryland streams exist and few more modern records survive, statements about ecological status must be made largely in the context of present day conditions. In this section, we present an overview of historical and present human influence on Maryland's streams and watersheds.

3.5.1 Forests and Forest Practices

In 1634, when Lord Calvert first arrived in Maryland, the State was nearly 95% forested (Besley 1916). Today, forests occupy only about 44% of the land area of Maryland, with the largest blocks of contiguous forest in western Maryland (Figure 3-5). More dramatic is the fact that only about 80 acres of old growth (not previously logged) forest exists today; this includes a 40 acre stand of eastern hemlock along a steep slope adjoining the Youghiogheny River and a 40 acre mixed hardwood stand in Belt Woods near the town of Bowie.

Even where forests have regrown, many are managed for timber production, causing more subtle but still substantial adverse effects on streams. The negative effects of many logging practices on stream water quality, temperature, erosion rates, evapotranspiration, and hydrology are well documented in the scientific literature (Hunter 1990, Murphy 1995); the loss of wood naturally falling into stream channels, however, has not been well documented (Masser and Sedell 1994). Both historical and modern forestry management has viewed the senescence and death of trees as wasteful and potentially harmful to forest health. For these reasons, forest practices rarely allow any large woody debris to enter streams. As a result, virtually no stream in Maryland has the abundance of large woody debris that likely existed before European settlement. Because wood in streams creates important habitat for organisms, alters channel morphology and bank erosion rates, and helps sequester or delay the downstream passage of nutrients, the loss of woody debris has been and continues to be a major influence on stream condition in Maryland.

3.5.2 Agriculture and Urbanization

Early settlers were drawn to Maryland by its diverse natural resources. The region provided favorable soils, topography, and climate for agriculture (especially tobacco), as well as natural harbors and waterways to facilitate the transport of goods, services, and people. By the early 1700s, European settlement was extensive, and an elaborate system of ditches was created to drain wetlands for agricultural use. The burgeoning economy led to the development of more urban centers and by 1776 the cities of Annapolis, Baltimore, Frederick, and Hagerstown had been established. Water-borne diseases, including malaria, yellow fever, and cholera were prominent in urban areas where raw sewage accumulated in open ditches and contaminated waterways. In addition to human health hazards, the quality of the region's rivers and bays deteriorated. Deforestation hastened erosion and increased sedimentation of the Bay's tributaries. Several tobacco ports, including Joppatowne, Port Tobacco, and Upper Marlboro were closed as channels filled with sediment and became unnavigable. It should be noted that each ton of sediment from overland runoff can destabilize stream channels and generate many more tons of sediment from increased streambank erosion (Rosgen 1996).

The 19^{th} and early 20^{th} centuries wrought numerous other changes to stream resources. With the advent of larger farm machinery during the Industrial Revolution, hedgerows and stream buffers were removed to increase efficiency and productivity. As a result, surface runoff and sediment loading to streams increased and stream conditions further deteriorated. This long history of exploiting the land left an imprint of the character of streams even after the 1960s, when soil erosion control practices on agricultural and urban lands first began reducing the amount of sediment entering into Maryland streams.

Agriculture has also had an effect on water chemistry in Maryland streams. As the agriculture industry grew and matured, increasing amounts of nutrients were added to fields to boost productivity. Today, nitrogen concentrations in streams are elevated in most areas of the State and phosphorous concentrations are high near large poultry and

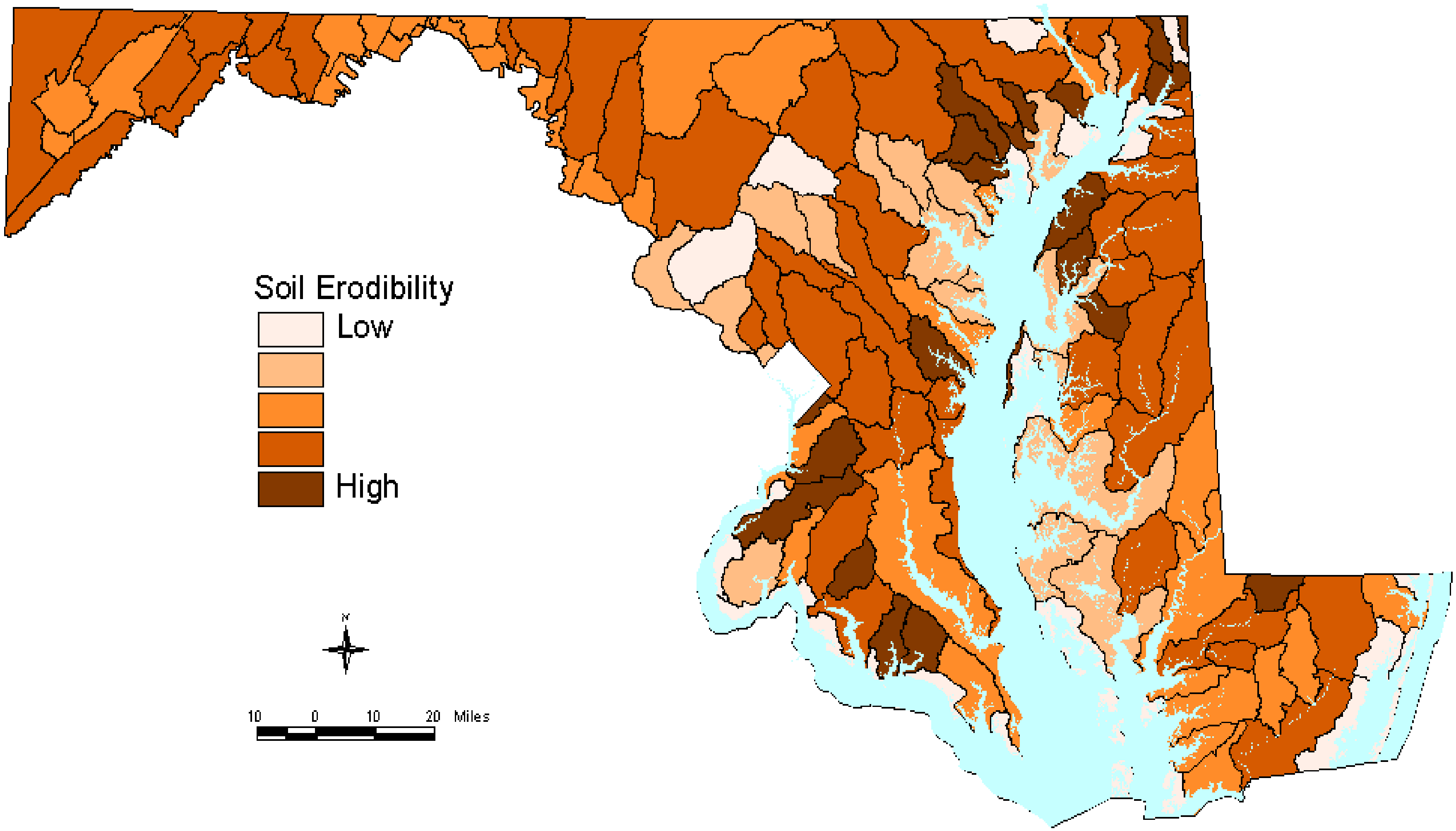


Figure 3-4. Soil erodibility map of Maryland (MDNR, Watershed Management and Analysis Division)

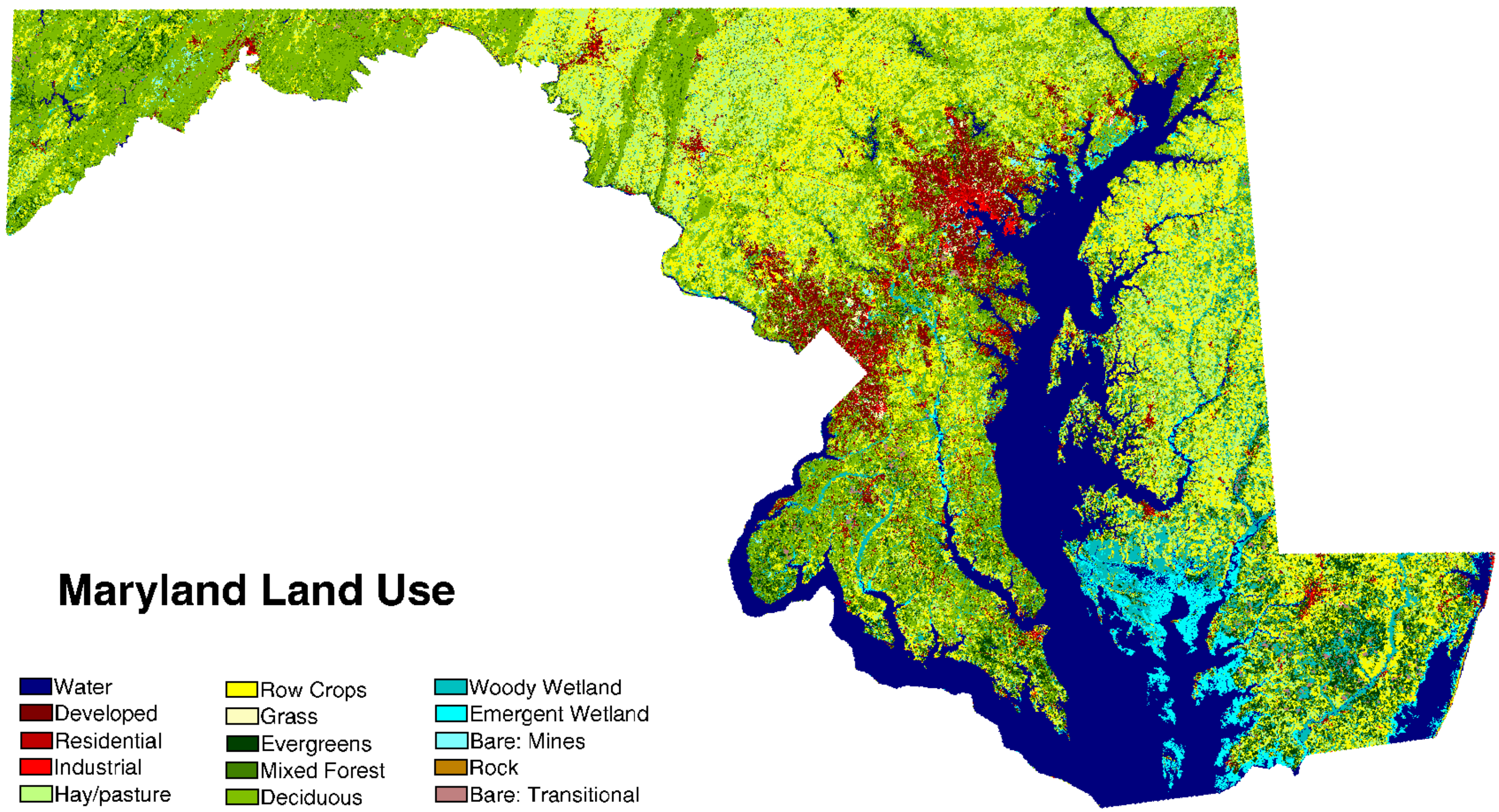


Figure 3-5. Land use map of Maryland (Multi-Resolution Land Characteristics data)

hog production operations. In addition, limestone is routinely applied to cropland, especially on the calcium-poor Coastal Plain. The addition of nutrients and limestone has affected the metabolism and productivity of many of Maryland's streams; in many cases, it has altered the biological community as well. For example, the addition of buffering capacity via limestone applications on the Coastal Plain has probably reduced the populations of acid-tolerant endemic species (as they are out-competed by acid-sensitive invaders).

After World War II, a new type of development, suburbs, arose on the outskirts of cities in Maryland and elsewhere as citizens sought to escape from the urban lifestyle. Over time, agricultural and forested lands adjacent to cities were converted to suburban housing and industries, creating more and more impervious surfaces. This development was accompanied by a network of roads (Figure 3-6). Although road density is highest in the Baltimore-Washington corridor, there are essentially no roadless watersheds in Maryland. In addition to providing a conduit for rapid stormwater runoff into streams, many roads also alter channel morphology or create barriers to fish migration.

At present, the density of humans in Maryland is about 1.3 people per acre (USCOM 1992) . Population density is greatest around the Baltimore-Washington metropolitan area, and lowest in western Maryland and most portions of the Eastern Shore (Figure 3-7). In general, the higher the human population density, the greater the ecological impacts on streams and stream communities. These impacts include increased dumping of contaminants, increased risk of toxic spills, increased effects of motor vehicle operation, increased likelihood of channelization and piping of streams, and more rapid stormwater runoff.

3.5.3 Fur Trade

One of the first impacts to Maryland streams during European colonization was the extirpation of the beaver population from the State. Formerly abundant, beavers altered stream ecosystems by raising water tables, trapping nutrients, altering channel morphology and gradient, creating openings in the forest, and adding woody debris. As beavers were eliminated, stream channels became less sinuous and habitat diversity was reduced. Today, reintroductions and a reduced demand for fur have resulted in a resurgence of beaver in many areas of the State; nonetheless, beaver densities are still well below historical levels.

3.5.4 Mining

With the advent of the Industrial Revolution, there was a new demand for raw materials for building and energy in Maryland. Sand, gravel, and rock quarries (many along streams and rivers) sprang up to fill the need; today there are many such facilities across the State. In most cases, the alteration of stream habitats has been relatively localized. However, the mining of coal in the Appalachian Plateau has had a pronounced effect on streams in that region. In 1929, runoff of water used to fight a fire in a gob pile (coal mine tailings) at Crellin, West Virginia, destroyed virtually all life in the Youghiogheny River for as long as 40 years (Powell 1967). In streams of the North Branch of the Potomac River, acid mine drainage (AMD), primarily from abandoned deep mines, has created a legacy of severe impairment in a number of streams as well as the mainstem river. To treat the problem, calcium is being added via automated dosers in several locations; the mitigative effects of mechanical dosers, however, cease when funds to operate them are withdrawn. The impairment associated with AMD includes cementing of substrates, addition of fine sediment, high levels of heavy metals, and low pH.

3.5.5 Air Impacts

As the population and industrial base of Maryland and other states in the region has expanded, so too has the use of coal and petroleum products for energy. As a consequence of combustion, nitrogen and sulfur oxides are released into the atmosphere. Because Maryland is situated within the "belt of prevailing westerlies," atmospheric pollution is transported to the State from the Midwest. For example, the Chesapeake Bay airshed is much larger than its watershed and includes parts of twelve states (Figure 3-8). While the deposition of atmospheric contaminants such as acid deposition across Maryland is relatively even (Bartoshesky et al. 1987), the effects on streams vary considerably by physiographic region according to the natural buffering capacity of the soils. The Coastal Plain, portions of the Blue Ridge and Piedmont, and Appalachian Plateau are sensitive to acidic deposition. In contrast, most of the Piedmont, the remaining portions of the Blue Ridge, and Valley and Ridge provinces are well buffered and resistant to acidification.

3.5.6 Water Impacts

As the pace of colonization and development of the land in Maryland increased, the streams and rivers of the State were

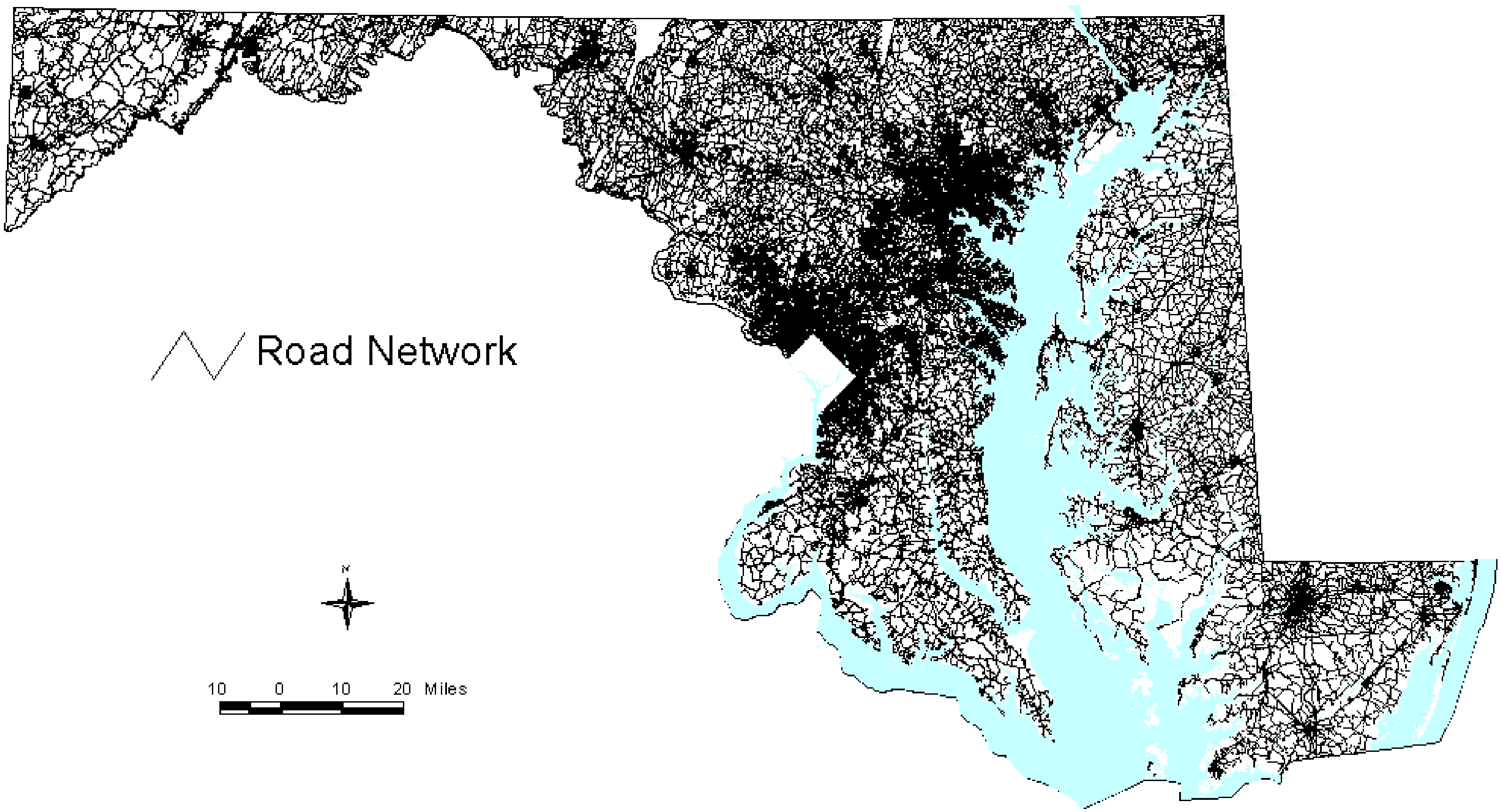


Figure 3-6. Road network map of Maryland (Maryland State Highway Administration)

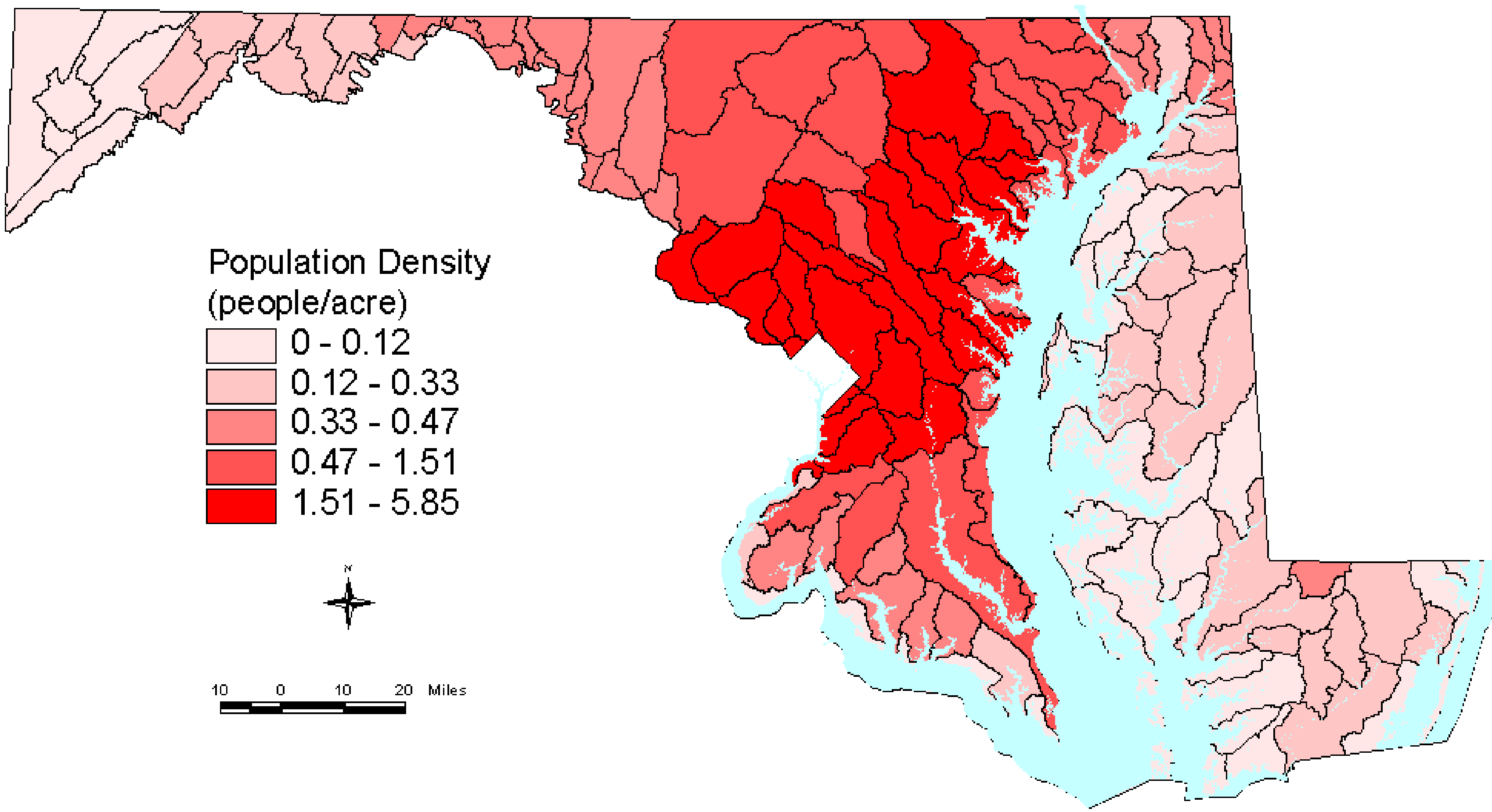


Figure 3-7. Population density map of Maryland based on 1990 census (MDNR, Watershed Management and Analysis Division)

CHESAPEAKE BAY
AIRSHED AND WATERSHED

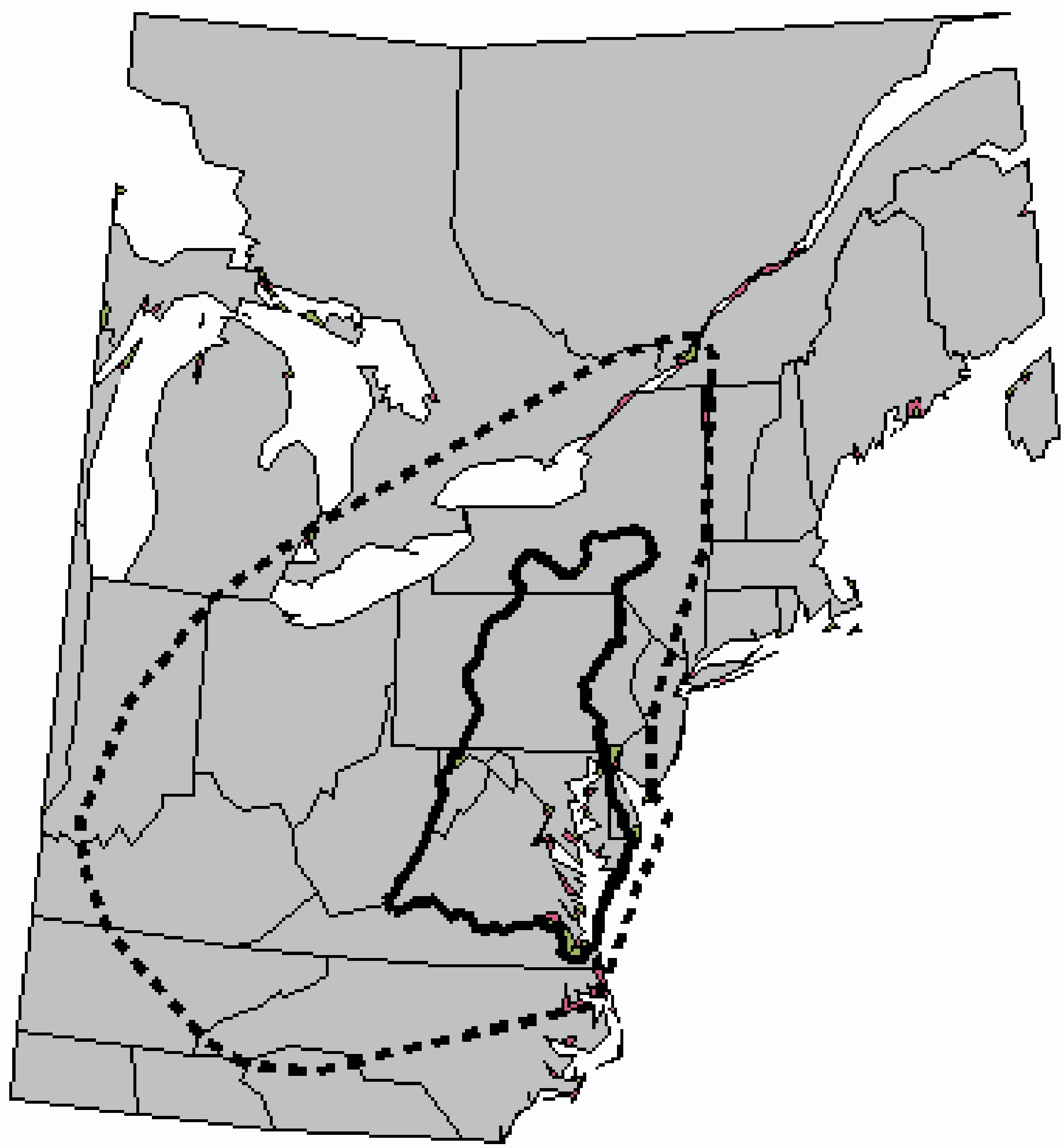


Figure 3-8. Airshed and watershed map for the Chesapeake Bay. Dotted line indicates airshed, solid line indicates watershed.

increasingly utilized for power, drinking water, and other uses. Today, more than 1,000 man-made barriers to fish movement are known to exist in areas potentially used by migratory species; there may be many more barriers in areas above where migration is currently possible (Figure 3-9). These barriers have restricted the abundance and distribution of aquatic species such as the American eel, once a dominant stream fish in many basins of the State. The loss of migratory species from local aquatic communities needs to be considered when developing and applying indicators of biological integrity for streams.

In addition to intentional and unintentional blockages to stream passage, stream channels have been converted into conduits for flood transport in Maryland's urban areas, especially the Baltimore-Washington metropolitan area. Typically, natural streams are transformed into concrete trapezoids to speed the flow of flood waters; these artificial channels provide essentially no useable habitat for aquatic organisms.

With increases in human population density, the consumptive and non-consumptive uses of water have also grown. In many areas of the State, declining well levels indicate that consumption rates may be exceeding recharge rates (USGS 1996), potentially reducing streamflows as well. Many streams have unpermitted water withdrawal systems on them; such water withdrawals during low flow conditions in the summer frequently result in increased water temperatures and less physical habitat available to organisms. In addition, higher levels of imperviousness in Maryland's watersheds have reduced groundwater recharge via infiltration. This phenomenon is especially pronounced in urban areas and often results in substantial reductions in habitat quantity and quality.

3.5.7 Summary of Human Influences

As described above, stream conditions in Maryland have been greatly influenced by both natural and human-induced changes to the environment. In addition to accounting for the natural variation among regional and local settings, an accurate assessment of Maryland streams needs to consider that even areas with little human activity today may have been dramatically influenced by historical impacts. Indeed, because of diffuse effects such as acidic deposition, no truly pristine streams exist in Maryland today. The fact that all the landscapes in the State have been modified from their natural condition should be kept in mind when evaluating data in this report; it is especially important when assessing stream condition using reference-based indicators. The history of human influences on Maryland streams sets obvious limits on the number of high quality streams that can be preserved and the level of integrity to which they can be restored. Therefore, it is critical that natural resource managers develop an appropriate vision of desired conditions for Maryland streams and view the results of the Survey in that context.

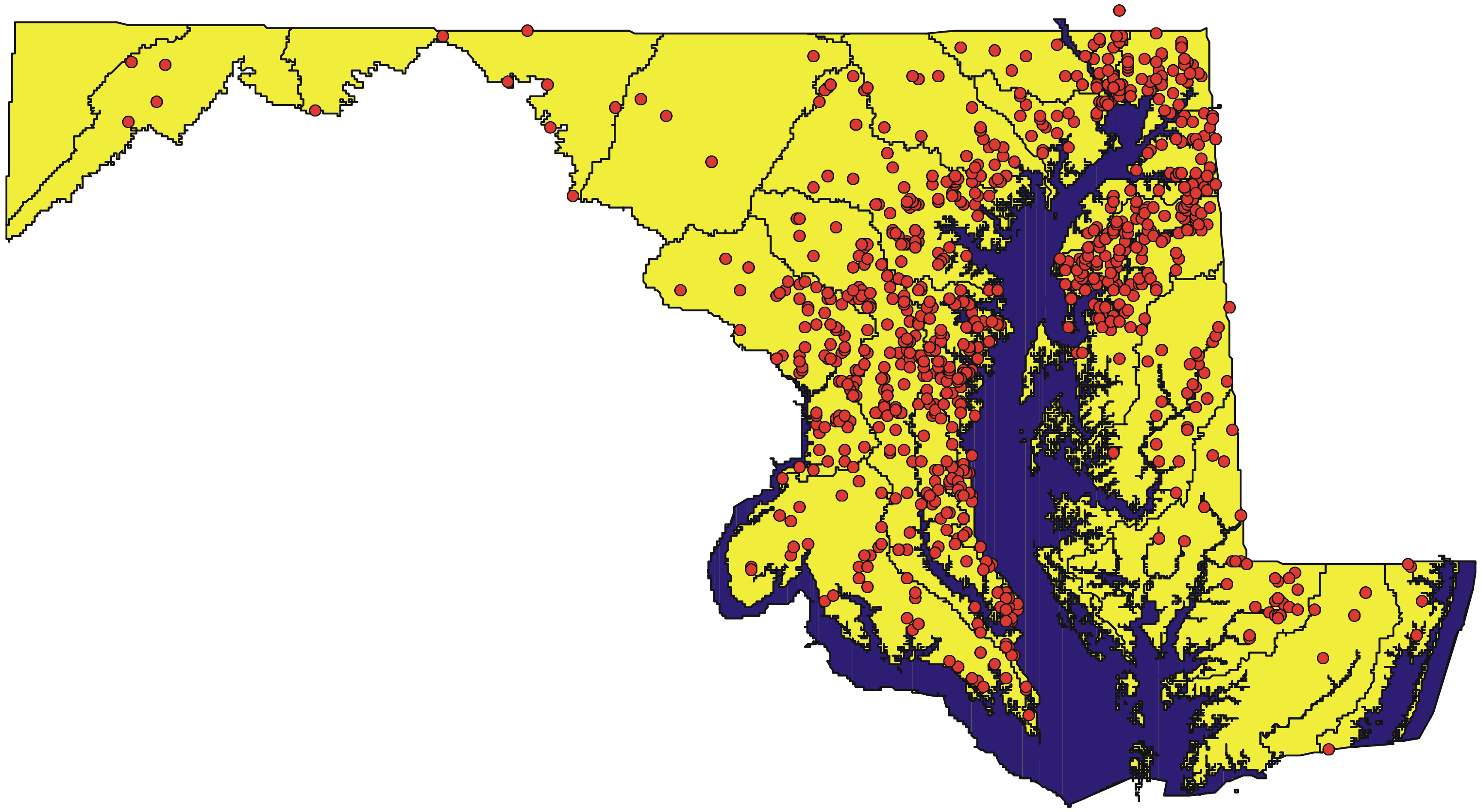


Figure 3-9. Map of dams and other barriers to fish migration in Maryland (Maryland Department of Natural Resources Fisheries Service, unpublished data)

4 CHARACTERIZATION OF BIOLOGICAL RESOURCES

This section highlights the overall results of biological sampling conducted at first- through third-order, non-tidal streams sampled in the statewide 1995-1997 Maryland Biological Stream Survey (MBSS or the Survey). The abundance and diversity of fish species are presented, including a special focus on gamefish and an evaluation of fish health reflected by observed anomalies. This section also includes general information on benthic macroinvertebrates, amphibians and reptiles, mussels, and aquatic vegetation.

The probability-based sampling design of the Survey allows parameters of interest, such as fish abundance, to be estimated on either a basinwide or statewide basis. This section reports statewide estimates based on sites sampled in the three-year Survey. Selected basin results have been included as highlights to the discussion. Other basin-specific estimates are reported in separate reports for the basins sampled in 1995 (Roth et al. 1997, Appendix F), 1996 (Roth et al. 1998, Appendix E), and 1997 (Roth et al. 1999). The Survey was designed so that the number of sites is proportional to the number of stream miles (by stream order) in a basin (Appendix B, Tables B-1 and B-2). Although a sufficient number of sites were sampled per basin, basin estimates from the smaller basins (including the Bush, Elk, Choptank, and Nanticoke/Wicomico) are more sensitive to the influence of extreme values at one or two sites compared to larger basins. Here, and throughout the report, standard errors are provided as a measure of the variability of the estimates.

4.1 FISH

4.1.1 Fish Abundance, Biomass, and Species Richness

Throughout the three years of core MBSS sampling using the stratified random sampling design, 83 fish species were collected at the 905 segments sampled during the summer; two additional species were collected at supplemental qualitative electrofishing sites. The total number of species collected was 85 (Table 4-1; Appendix C, Table C-1). These represent 72% of the total number of freshwater fish species occurring in Maryland (Lee et al. 1981). A list of freshwater fish species historically or currently known to occur in Maryland, but not recorded in the Survey, is included in Appendix C, Table C-2.

Most species were collected in the Patuxent basin (57 species at core MBSS and supplemental sites combined). The lowest number occurred in the Youghiogheny and Nanticoke/Wicomico basins (28 species). The total number of species in each of the other basins ranged from 29 to 54 (Table 4-2).

Three species had widespread distributions, occurring in all basins sampled. These species, all in the family Centrarchidae, are the bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and pumpkinseed (*Lepomis gibbosus)*. Five additional species occurred in every basin but one. Six species occurred in only one basin: the longnose gar (*Lepisosteus osseus*), striped shiner (*Luxilus chrysocephalus*), shorthead redhorse (*Moxostoma macrolepidotum*), flier (*Centrarchus macropterus*), johnny darter (*Etheostoma nigrum*), and stripeback darter (*Percina notogramma*). Two species were found only in non-randomly selected supplemental sampling sites: the Atlantic menhaden (*Brevoortia tyrannus*) and banded darter (*Etheostoma zonale*).

Among the fish collected in the Survey were several occurrences not often reported in Maryland. Checkered sculpin (*Cottus* sp. nov.), an undescribed species endemic to Maryland, were found at one second-order site in the Middle Potomac basin and in several first- and second-order sites in the Upper Potomac basin. Cutthroat trout (*Oncorhynchus clarki*), native to the Rocky Mountains but recently introduced into Maryland, were found at three third-order sites in the North Branch Potomac basin and one second-order site in the Patapsco basin. In addition, six species listed by the Maryland DNR Wildlife and Heritage Division as rare were collected: mud sunfish (*Acantharcus pomotis*), ironcolor shiner (*Notropis chalybaeus*), logperch (*Percina caprodes*), flier, glassy darter (*Etheostoma vitreum*), and stripeback darter. See Chapter 12 for further discussion of rare species.

The number of species per 75-m segment varied throughout the basins (Figure 4-1, Table 4-2). Mean per-segment species richness was generally highest in the basins of the eastern and central portions of the state, with a high of 12.8 in the Elk basin. In comparison, lower species richness was reported in the higher-elevation streams of western Maryland, where the mean number of fish species per segment was 3.7 in the North Branch Potomac basin,

Table 4-1. Fish species found at core MBSS and Supplemental sites, by basin

Fish Family	Fish Species	Notes	Youghiogheny	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank	Nanticoke/Wicomico	Pocomoke
Lampreys: Petromyzontidae	American brook lamprey						X		X										
	Least brook lamprey						X	X	X	X	X		X		X	X	X	X	X
	Sea lamprey	d					X	X	X			X	X	X	X	X			
Gars: Lepisosteidae	Longnose gar																		X
Freshwater Eels: Anguillidae	American eel			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Herrings: Clupeidae	Atlantic menhaden															S			
	Gizzard shad								X	X									
Pikes: Esocidae	Chain pickerel	iy, g	X		X		X	X	X	X	X				X	X	X	X	X
	Redfin pickerel	iy, g	X				X	X	X	X	X		S		X	X	X	X	X
Mudminnows: Umbridae	Eastern mudminnow						X	X	X	X	X		X		X	X	X	X	X
Minnows: Cyprinidae	Blacknose dace		X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	Bluntnose minnow		X	X	X	X	X		X		X	X	X	X					
	Central stoneroller		X	X	X	X	X		X		X	X		X					
	Comely shiner				S	X	X				X		X				X		
	Common carp	i		S	X	X	X	S			X		S	X	S				
	Common shiner		X	X	X	X	X	X	X		X	X	X	X	X				
	Creek chub		X	X	X	X	X	X	X		X	X	X	X	X				
	Cutlips minnow			X	X	X	X		X		X	X	X	X	X				
	Eastern silvery minnow					X	X	X	S				X		X				
	Fallfish			X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Fathead minnow	i	X		X	X	X	X	X		X	X							
	Golden shiner		X	S	S	X	X	X	X	X	X		S	X	X	X	X	X	X
	Goldfish	i			S		X	S		X	X		X						
	Ironcolor shiner							X									X		
	Longnose dace		X	X	X	X	X		X		X	X	X	X	X				
	Pearl dace				X	X													
	River chub		X	X	X	X	X		X		X	X	X	X	X				
	Rosyface shiner			S	S	X					X		X	X	X				
	Rosyside dace			X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	Satinfin shiner					X	X	X	X	X	X	X	X	X	X	X	X		X
	Silverjaw minnow					X	X				X	S							

Table 4-1. Cont'd

Fish Family	Fish Species	Notes	Youghiogheny	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank	Nanticoke/Wicomico	Pocomoke
Minnows: Cyprinidae (cont'd)	Spotfin shiner			X	X	X	X				X			X					
	Spottail shiner			S	X	X	X	X	X	X	X	S	S	X	X	X		S	
	Striped shiner		X																
	Swallowtail shiner					X	X	X	X	X	X	X	X	X	X	X	X		X
Suckers: Catostomidae	Creek chubsucker			X	X	X	X	X	X	X	X		X		S	X	X	X	X
	Golden redhorse			X	S	S													
	Northern hogsucker		X	X	X	X	X		X		X	X	X	X	X				
	Shorthead redhorse								X										
	White sucker		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Catfishes: Ictaluridae	Brown bullhead		X	X		X	X	X	X	X	X	S	X	X	S	X	X	X	X
	Channel catfish	ic			S	X			S					S					X
	Margined madtom	iy		X	S	X	X	X	X		X	X	X	X	X	X	X	X	X
	Tadpole madtom							X	X						S	X	X	X	X
	White catfish	iy					X		S							S			X
	Yellow bullhead		X	X	X	X	X	X	X		X	X		X		S	X	X	X
Trouts: Salmonidae	Brook trout	g	X	X	S	X					X	X		X					
	Brown trout	g,i	X	X	X	X	X		X		X	X		X	X				
	Cutthroat trout	g,i		X	S						X								
	Rainbow trout	g,i	X	X	X	X	X		X	X	X	X	X	S	X				
Pirate Perches: Aphredoderidae	Pirate perch							X	X							X	X	X	X
Killifishes: Fundulidae	Banded killifish				S	X	X	X	S		X			X	X	X		S	
	Mummichog						X	S	X	X	X	S				X			X
Livebearers: Poeciliidae	Mosquitofish						X	X	X	X	X	S				S		X	X
Sculpins: Cottidae	Checkered sculpin				X	X													
	Mottled sculpin		X	X	X	X	X		X		X	X	X	X	X			X	
	Potomac sculpin			X	X	X	X												
Striped Basses: Moronidae	Striped bass	g							S		X				X				
	White perch					S	X	S	S					S	S	X		S	X
Sunfishes: Centrarchidae	Banded sunfish									X			S						X
	Black crappie	ic			X			X	X	X	X					X	X	X	X
	Bluegill	ic	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 4-1. Cont'd

Fish Family	Fish Species	Notes	Youghiogheny	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank	Nanticoke/Wicomico	Pocomoke
Sunfishes: Centrarchidae (cont'd)	Bluespotted sunfish						X	X	X		X				S	X	X	X	X
	Flier							X											
	Green sunfish	ic	X	X	X	X	X	X	X	X	X	X	X	X		X			
	Largemouth bass	ic, g	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Longear sunfish	ic			S	X						X							
	Mud sunfish															S	X	X	X
	Pumpkinseed	iy	X	X	X	X	X	X	X	X	X	S	X	X	X	X	X	X	X
	Redbreast sunfish	iy		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Rock bass	ic	X	X	X	X	X				X	X		X					
	Smallmouth bass	ic,g	X	X	X	X	X		X		X	X	X	X	X				
	Warmouth							X	X										
Perches: Percidae	Banded darter	i												S					
	Fantail darter			X	X	X	X					X							
	Glassy darter								X									X	X
	Greenside darter			X	X	X	X												
	Johnny darter		X																
	Logperch													X	X				
	Rainbow darter			X	S														
	Shield darter								X			X		X			X		
	Stripeback darter								X										
	Swamp darter							X								X	X	X	X
	Tessellated darter			S	S	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Yellow perch	iy	X	X				X	X	X	X			S	S	X	X	X	X

Notes:

X - Indicates that the species was caught at a random MBSS site
S - Indicates that the species was caught at a non-random supplemental site
d - Diadromous
g - Gamefish
i - Introduced
ic - Introduced to the Chesapeake drainage only
iy - Introduced to the Youghiogheny drainage only

Table 4-2. Fish species richness for basins sampled in the 1995-1997 MBSS

	Number of Species Collected in Basin*	Mean Number of Species per Segment	Standard Error
Basin			
Youghiogheny	28	5.2	0.7
North Branch Potomac	41	3.7	0.4
Upper Potomac	49	4.5	0.5
Middle Potomac	50	8.6	0.7
Potomac Washington Metro	54	9.3	0.8
Lower Potomac	43	8.1	1.0
Patuxent	57	8.4	0.6
West Chesapeake	29	3.7	0.8
Patapsco	52	8.6	0.8
Gunpowder	39	8.3	0.9
Bush	38	11.0	1.9
Susquehanna	43	9.6	1.1
Elk	42	12.8	2.6
Chester	37	8.6	1.4
Choptank	30	12.4	2.3
Nanticoke/Wicomico	28	8.4	1.8
Pocomoke	32	10.7	2.2
Stream Order			
1	57	5.8	1.0
2	75	10.9	1.3
3	79	15.0	1.6
All	85	7.7	1.0

* Includes species collected at core MBSS and supplemental sites

reflecting natural differences due to geography and stream size, as well as impacts of acid mine drainage. As would be expected, species richness increased with stream order across all basins (Figure 4-2), with an average of 5.8 fish species per segment for first-order streams, 10.9 for second-order, and 15.0 for third-order streams.

Statewide density and abundance estimates are presented for each game and nongame fish species (Appendix E, Tables E-3 and E-4). The total catch from two electrofishing passes was used along with the total number of stream miles in the basin (by stream order) to estimate density of each species as the number of individuals per stream mile. Raw densities were then adjusted for the capture efficiency of the double-pass electrofishing method (Heimbuch et al. 1997). Adjusted densities were used to estimate adjusted total abundance, the number of individuals per basin, for each species. All abundance values reported here have been adjusted for capture efficiency.

Statewide, the most abundant stream fishes were (1) blacknose dace (*Rhinichthys atratulus*), estimated at 1,970

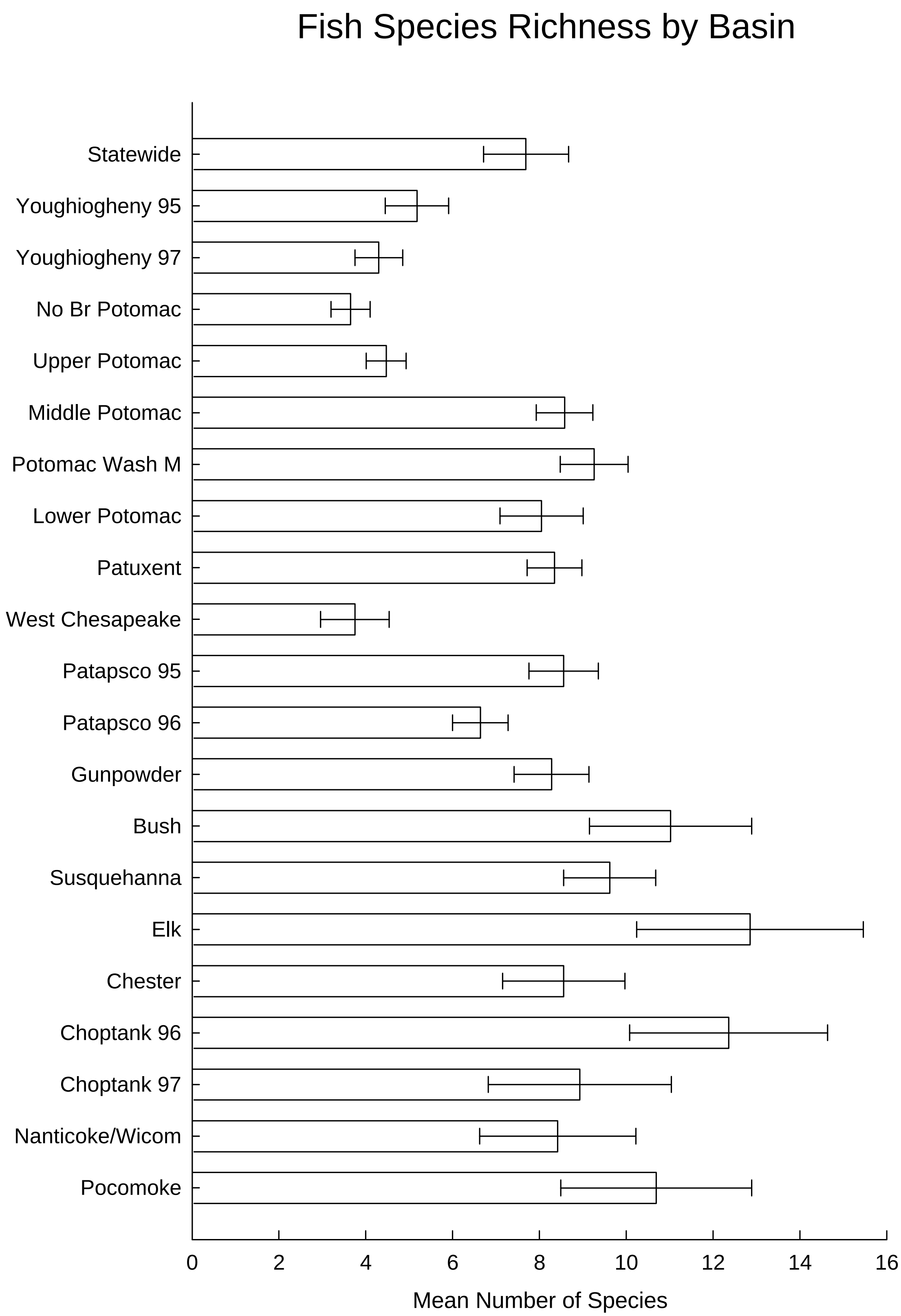


Figure 4-1. Per-segment fish species richness (mean number of species per 75-m segment), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

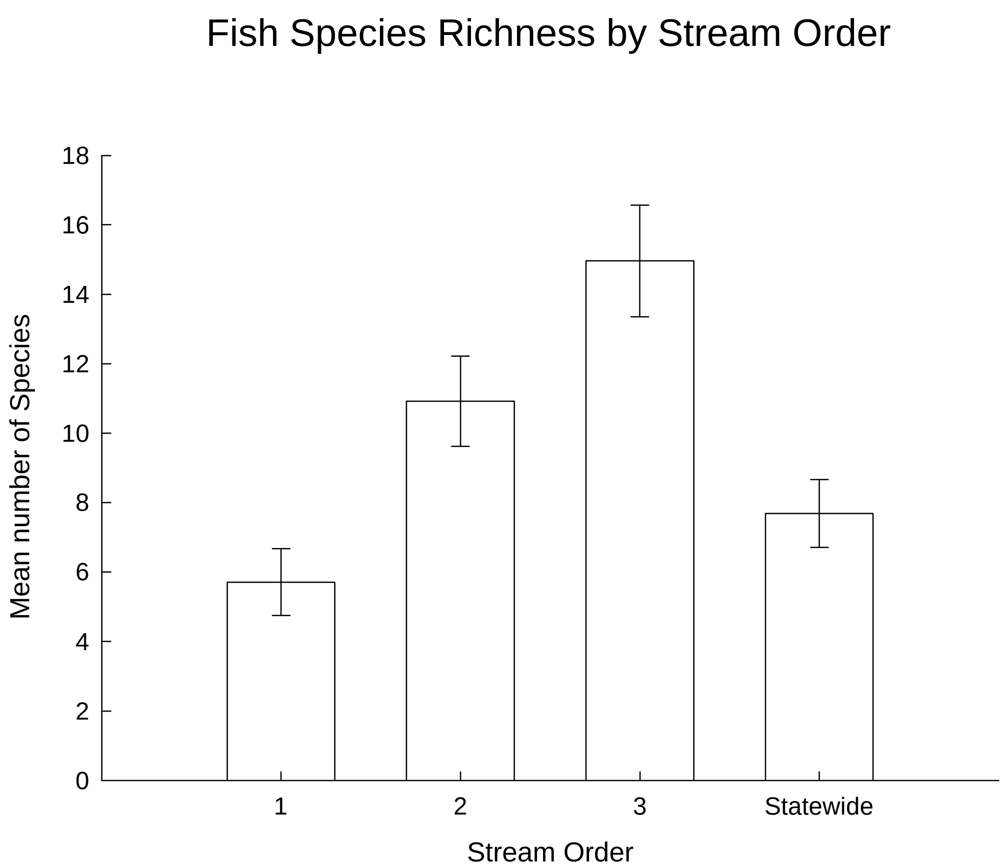


Figure 4-2. Per-segment fish species richness (mean number of species per 75-m segment), by stream order, for the 1995-1997 MBSS. Error bars signify ±1 standard error.

individuals per stream mile and nearly 11.6 million individuals statewide, and (2) mottled sculpin (*Cottus bairdi*), estimated at 1,370 individuals per stream mile and nearly 8.1 million individuals statewide. The most abundant gamefish species were (1) brook trout (*Salvelinus fontinalis*), with an estimated 54 individuals per stream mile and nearly 318,000 individuals statewide and (2) largemouth bass, with an estimated 53 individuals per stream mile and more than 311,000 individuals statewide.

Combining all species, mean fish density was estimated at 10,325 individuals per stream mile. Densities were also compared across all 17 basins and three stream orders (Figures 4-3 and 4-4; Table 4-3). Density was lowest in the North Branch Potomac, with an estimated 2,633 fish per stream mile. Density estimates in other basins ranged from 3,299 to 15,099 fish per stream mile. Densities were higher in second- and third- order streams (16,556 and 22,040 individuals per stream mile, respectively), and lower in first-order streams (6,821 individuals per stream mile).

Statewide, an estimated 4% of stream miles had no fish. Because many streams that drain small watersheds may naturally contain no fish, this estimate excluded stream miles located in watersheds of less than 300 acres (Roth et al. 1998; Figure 4-5). Seven basins contain stream miles with no fish in watersheds that are greater than 300 acres: the Youghiogheny (1997 sampling), North Branch Potomac, Upper Potomac, Middle Potomac, Patapsco (1996 sampling), Chester, and Pocomoke basins.

Fish biomass estimates (kilograms per stream mile) were derived from the aggregate weights of game and nongame fish species. Because adjustment for capture efficiency depends on data for individual species, no such adjustment was made for biomass estimates. To accurately calculate

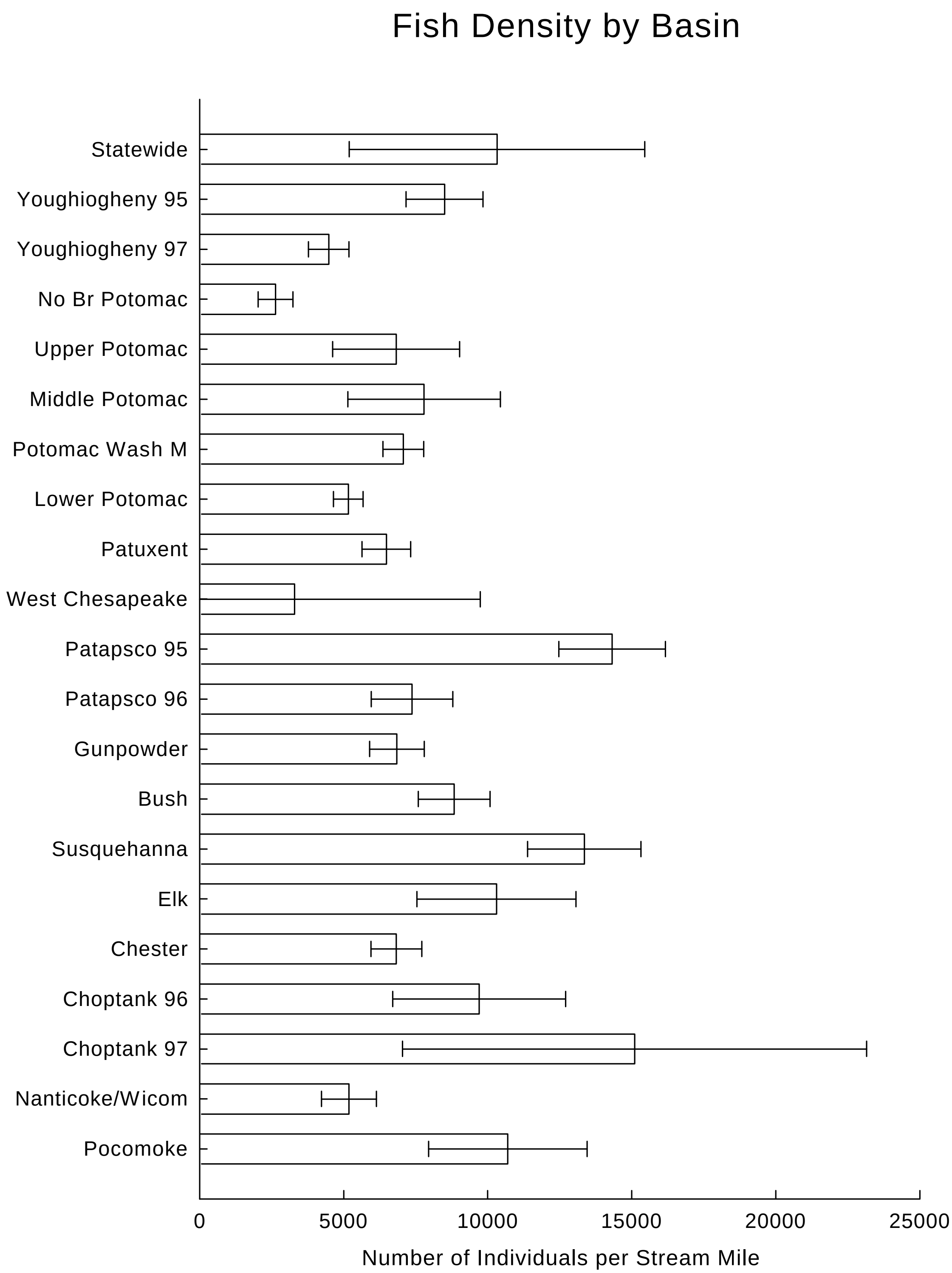


Figure 4-3. Fish density (number of individuals per stream mile), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Density estimates are adjusted for capture efficiency.

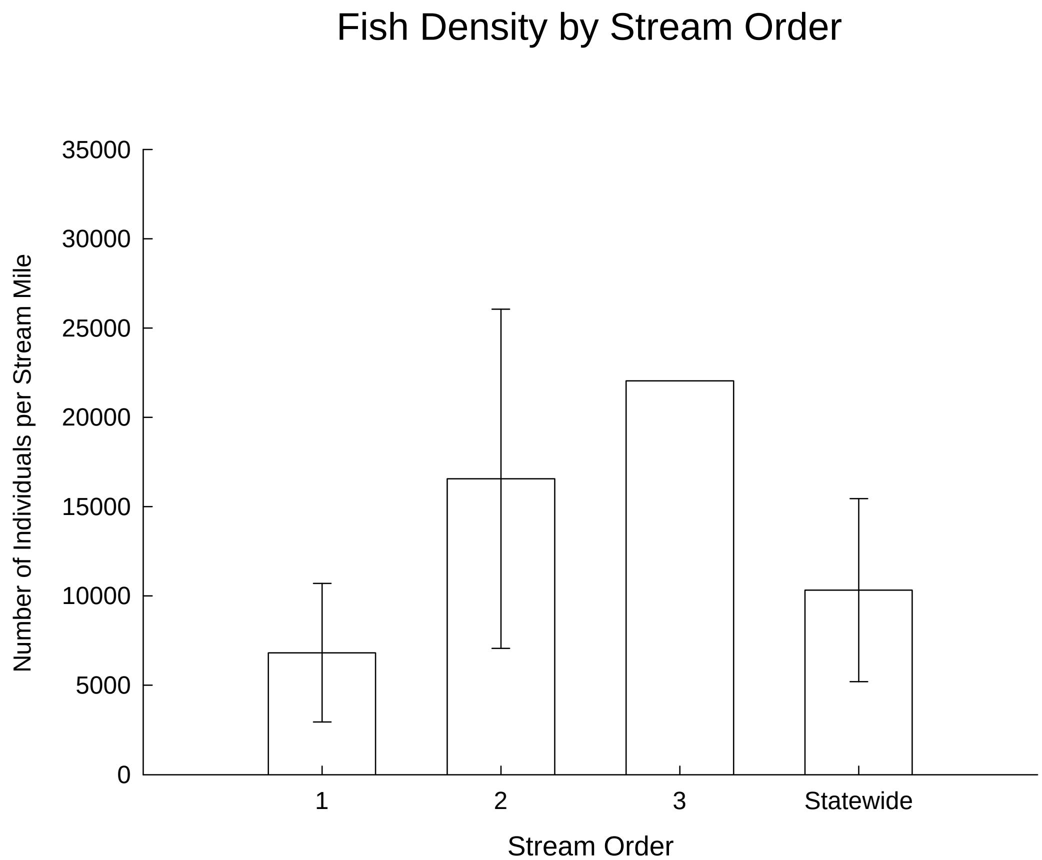


Figure 4-4. Fish density (number of individuals per stream mile) by stream order, for the 1995-1997 MBSS. Error bars signify ±1 standard error (lack of error bars indicate that variance is statistically undefined). Density estimates are adjusted for capture efficiency.

biomass adjusted for capture efficiency, actual biomass would need to be measured for each species individually. Size selectivity of the electrofishing gear may also bias biomass estimates.

Statewide, biomass was approximately 44.2 kg/stream mile. Biomass estimates ranged from about 18.0 kg per stream mile in the North Branch Potomac basin to 119 kg per stream mile in the Elk basin (Figure 4-6, Table 4-4). As would be expected, mean biomass was greater in second and third order streams (about 73.8 and 125.0 kg per stream mile, respectively) than in first order streams (about 24.1 kg per stream mile; Table 4-4).

4.1.2 Gamefish

The distributions of gamefish species varied across the state, as would be expected given physiographic differences in aquatic habitat (Table 4-1). Largemouth bass had the most widespread distribution, occurring in all basins. Smallmouth bass (*Micropterus dolomieu*) were present in 11 of the sampled basins. Striped bass (*Morone saxatilis*) were found at three Coastal Plain sites. Brook trout were found in seven of the basins; brown trout (*Salmo trutta*) were more widespread, occurring in ten basins. Rainbow trout (*Oncorhynchus mykiss*), a widely stocked species, were found in small numbers in 12 basins, while a few cutthroat trout (a recent introduction to Maryland) were found in the North Branch Potomac, Upper Potomac, and Patapsco basins.

The brook trout is an important native gamefish in Maryland streams (the other gamefish discussed above are introduced throughout most of their range in Maryland). Differences in density of brook trout were detected among basins and across stream orders (Figures 4-7 and 4-8). Statewide, the estimated density of brook trout is 54 individuals per stream mile. The 1997 sampling of the Youghiogheny basin had the greatest number of brook trout

Table 4-3. Estimated density (number of individuals per stream mile) for all fish (nongame fish and gamefish), for basins sampled in the 1995-1997 MBSS. Densities are adjusted for capture efficiency.

	Total Fish Density	Standard Error	Nongame Fish Density	Standard Error	Gamefish Density	Standard Error
Basin						
Youghiogheny 1995	8501.5	1336.2	8325.9	1339.6	175.6	53.3
Youghiogheny 1997	4478.3	702.9	4062.0	710.1	416.3	91.0
North Branch Potomac	2632.9	606.0	2539.4	607.5	93.4	27.9
Upper Potomac	6823.7	2204.0	6798.4	2203.6	25.3	7.9
Middle Potomac	7790.4	2648.1	7759.9	2647.9	30.4	12.5
Potomac Washington Metro	7073.3	710.0	7059.5	708.0	13.8	7.2
Lower Potomac	5158.8	517.0	5106.4	516.3	52.4	28.5
Patuxent	6481.1	845.9	6371.9	849.2	109.3	61.9
West Chesapeake	3299.0	6444.4	3155.5	6442.0	143.4	139.4
Patapsco 1995	14318.9	1849.5	14176.8	1850.1	142.1	47.5
Patapsco 1996	7372.3	1416.6	7188.6	1349.6	183.7	439.6
Gunpowder	6845.4	947.8	6581.3	951.4	264.0	68.7
Bush	8833.8	1246.1	8797.4	1247.4	36.0	17.4
Susquehanna	13353.0	1962.8	13072.7	1947.3	280.4	121.2
Elk	10303.9	2761.7	10231.7	2767.2	72.2	31.6
Chester	6830.2	883.1	6577.2	786.4	253.1	284.4
Choptank 1996	9706.4	3001.0	9660.0	3007.8	46.4	21.0
Choptank 1997	15099.2	8054.4	14910.3	8053.6	188.9	79.6
Nanticoke/Wicomico	5184.0	953.7	5152.6	958.3	31.5	39.8
Pocomoke	10698.6	2751.5	10694.4	2751.4	4.1	1.7
Stream Order						
1	6820.6	3870.7	6718.4	3815.4	102.2	62.7
2	16555.5	9500	16345.1	9590.1	201.2	121.1
3	22040.2	*	21601.2	*	438.6	*
Statewide	10324.9	5127.9	10169.5	5055.1	155.4	83.6

*Variance statistically undefined

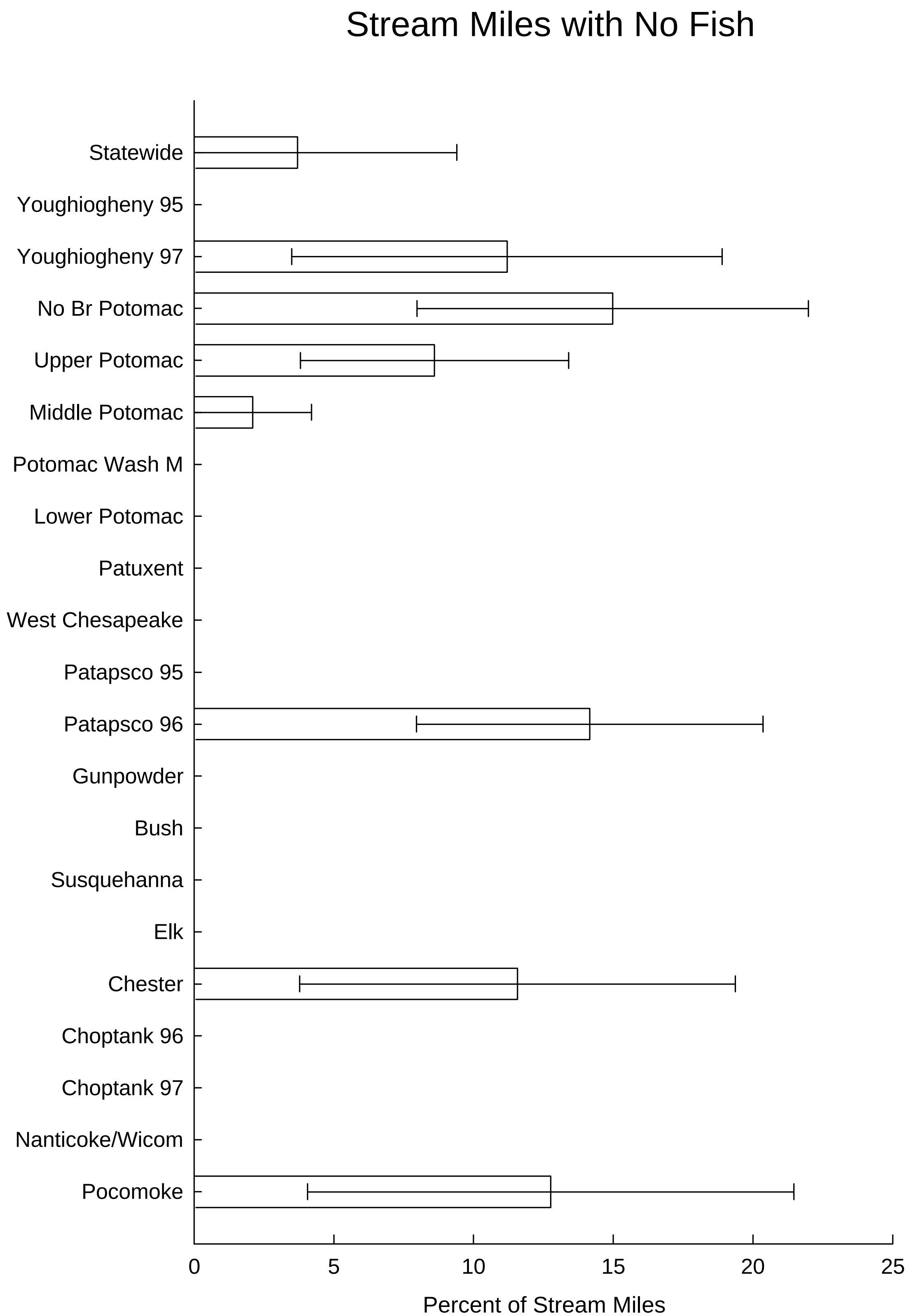


Figure 4-5. Estimated percentage of stream miles with no fish, statewide and for basins sampled in the 1995-1997 MBSS. Sites with watersheds < 300 acres were excluded from these estimates. Error bars signify ±1 standard error.

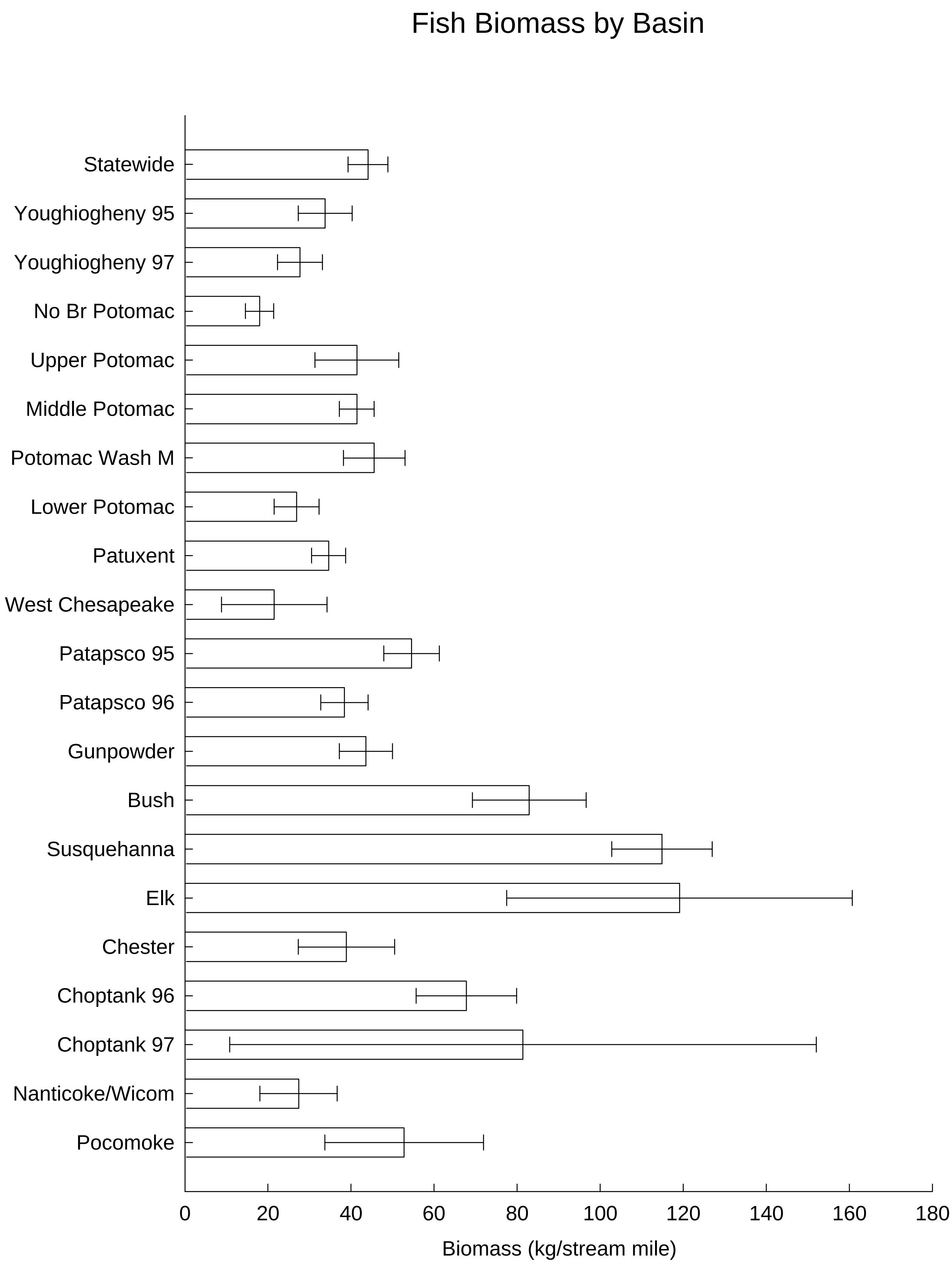


Figure 4-6. Fish biomass (kg per stream mile), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Biomass estimates are not adjusted for capture efficiency.

Table 4-4. Estimated biomass (kg/stream mile) for all fish (nongame fish, and gamefish), for basins sampled in the 1995-1997 MBSS. Estimates are not adjusted for capture efficiency.

	Total Fish Biomass	Standard Error	Nongame Fish Biomass	Standard Error	Gamefish Biomass	Standard Error
Basin						
Youghiogheny 1995	33.8	6.5	29.0	6.0	4.8	2.7
Youghiogheny 1997	27.7	5.4	19.9	4.6	7.8	2.7
North Branch Potomac	18.0	3.4	13.4	3.1	4.6	1.5
Upper Potomac	41.3	10.1	39.3	9.7	2.1	0.6
Middle Potomac	41.4	4.2	40.1	4.1	1.3	0.4
Potomac Washington Metro	45.6	7.4	45.0	7.4	0.7	0.3
Lower Potomac	27.0	5.4	25.5	5.1	1.5	1.0
Patuxent	34.6	4.1	32.7	4.0	2.0	0.7
West Chesapeake	21.5	16.7	21.1	16.4	0.4	0.3
Patapsco 1995	54.6	6.7	50.2	6.4	4.4	1.3
Patapsco 1996	38.4	5.7	35.7	5.4	2.7	0.7
Gunpowder	43.6	6.4	38.8	6.3	4.8	1.8
Bush	82.9	13.7	80.8	13.3	2.0	1.4
Susquehanna	114.9	19.1	108.5	18.7	6.3	2.6
Elk	119.1	41.6	103.7	36.9	15.4	23.8
Chester	38.9	11.6	36.4	11.3	2.5	10.2
Choptank 1996	67.8	12.1	65.8	12.3	2.1	1.8
Choptank 1997	81.5	70.6	75.6	61.0	5.9	9.8
Nanticoke/Wicomico	27.5	9.3	25.0	8.2	2.5	1.9
Pocomoke	52.9	19.1	52.7	19.1	0.2	0.2
Stream Order						
1	24.1	6.2	22.5	5.4	1.6	1.9
2	73.8	13.4	69.5	13.4	4.3	2.4
3	124.7	23.1	113.6	23.2	11.0	5.2
Statewide	44.2	4.8	411.9	4.9	3.1	1.6

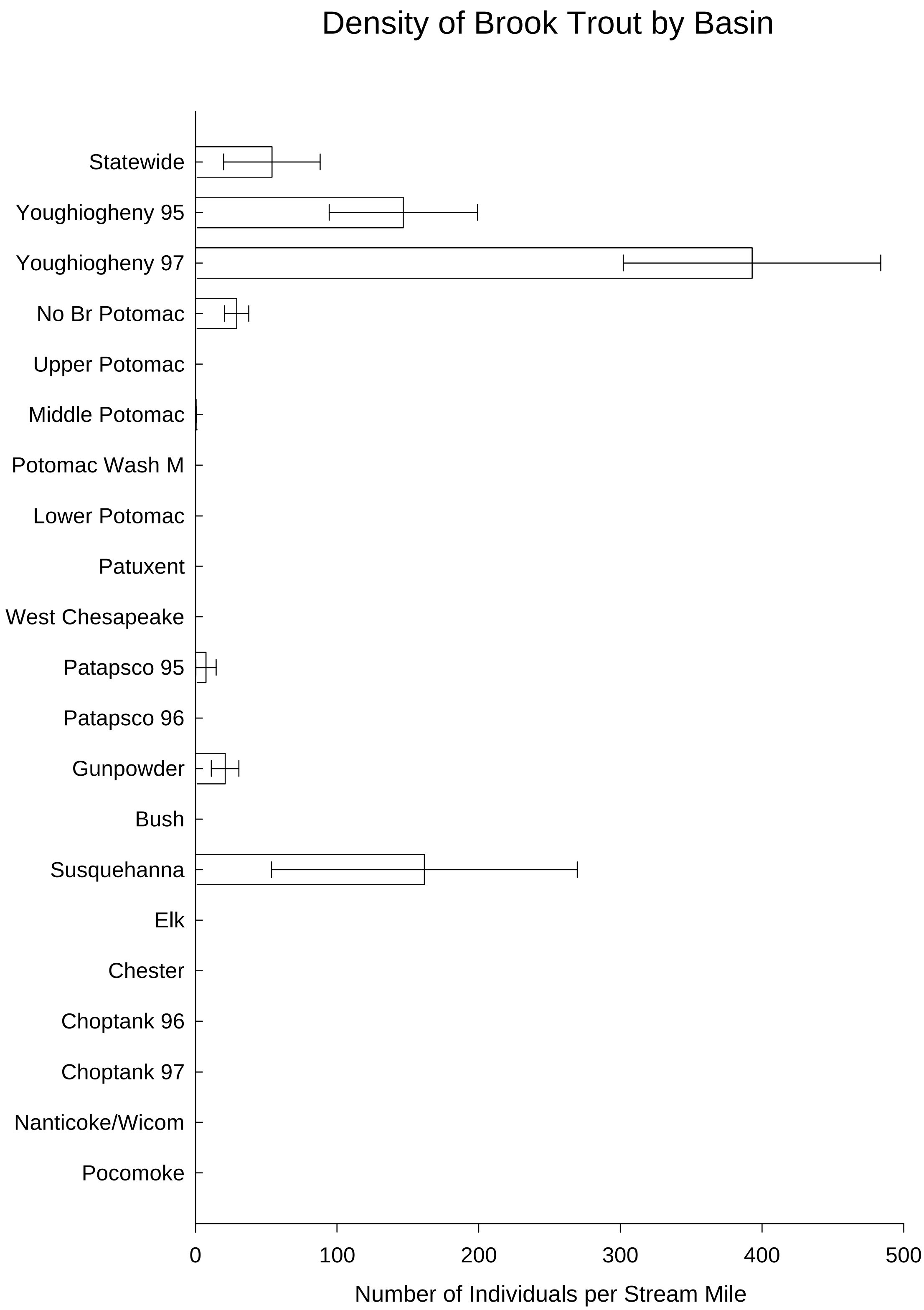


Figure 4-7. Density (number of individuals per stream mile) of brook trout (*Salvelinus fontinalis*), statewide and for the basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Density estimates are adjusted for capture efficiency.

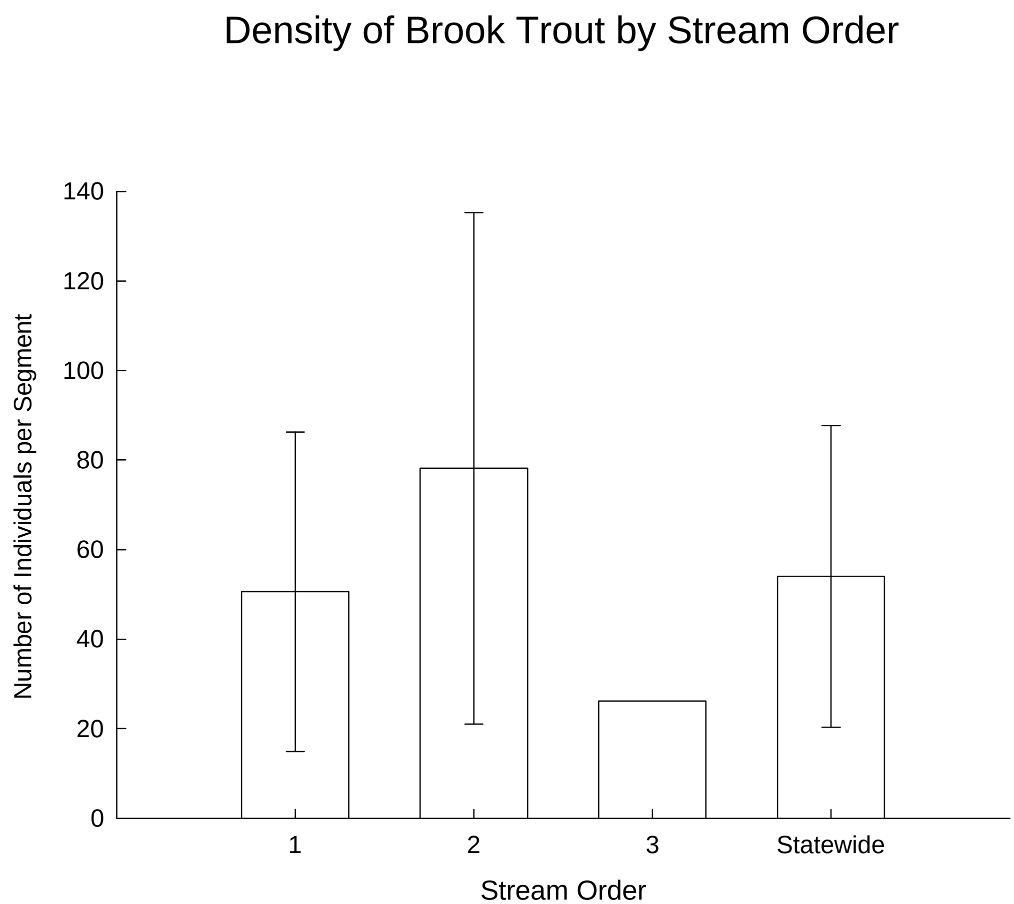


Figure 4-8. Density (number of individuals per stream mile) of brook trout (*Salvelinus fontinalis*), by stream order for the basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error (lack of error bars indicate that variance is statistically undefined). Density estimates are adjusted for capture efficiency.

individuals per stream mile (393 individuals per stream mile). The other basins that contained brook trout were: the Youghiogheny (1995 sampling), North Branch Potomac, Patapsco (1995 sampling), Middle Potomac, Gunpowder, and Susquehanna. Brook trout density also varied across stream orders, with third-order streams having fewer brook trout individuals per stream mile (26) than both first- and second- order streams (51 and 78, respectively).

The density, abundance, and biomass of combined gamefish species were calculated from MBSS data. Total gamefish density (Figures 4-9 and 4-10; Table 4-3) was greatest in the Youghiogheny (1997 sampling) and Susquehanna basins, where brook trout and brown trout were the dominant game species. The Gunpowder basin, dominated by brook trout and brown trout, and the Chester basin, dominated by largemouth bass, were also among the basins with greatest gamefish density. Over all basins and stream orders, the mean density of gamefish was 155 individuals per stream mile, with the greatest density in third-order streams (439 individuals per stream mile). Although first-order streams had a lower mean density of gamefish (102 individuals per stream mile), the estimated total abundance of gamefish inhabiting first-order streams is actually greater than that of third-order streams, given the greater total length of lower order streams throughout the basins. Aggregate gamefish biomass exhibited a slightly different pattern than did gamefish density (Figure 4-11, Table 4-4). The highest gamefish biomass occurred in the Elk basin and third-order streams had far greater gamefish biomass than did smaller streams, reflecting the populations of larger adult fish present in third-order streams. Many of the gamefish captured by the Survey were below legal or catchable size limits, as might be expected given the number of small streams sampled.

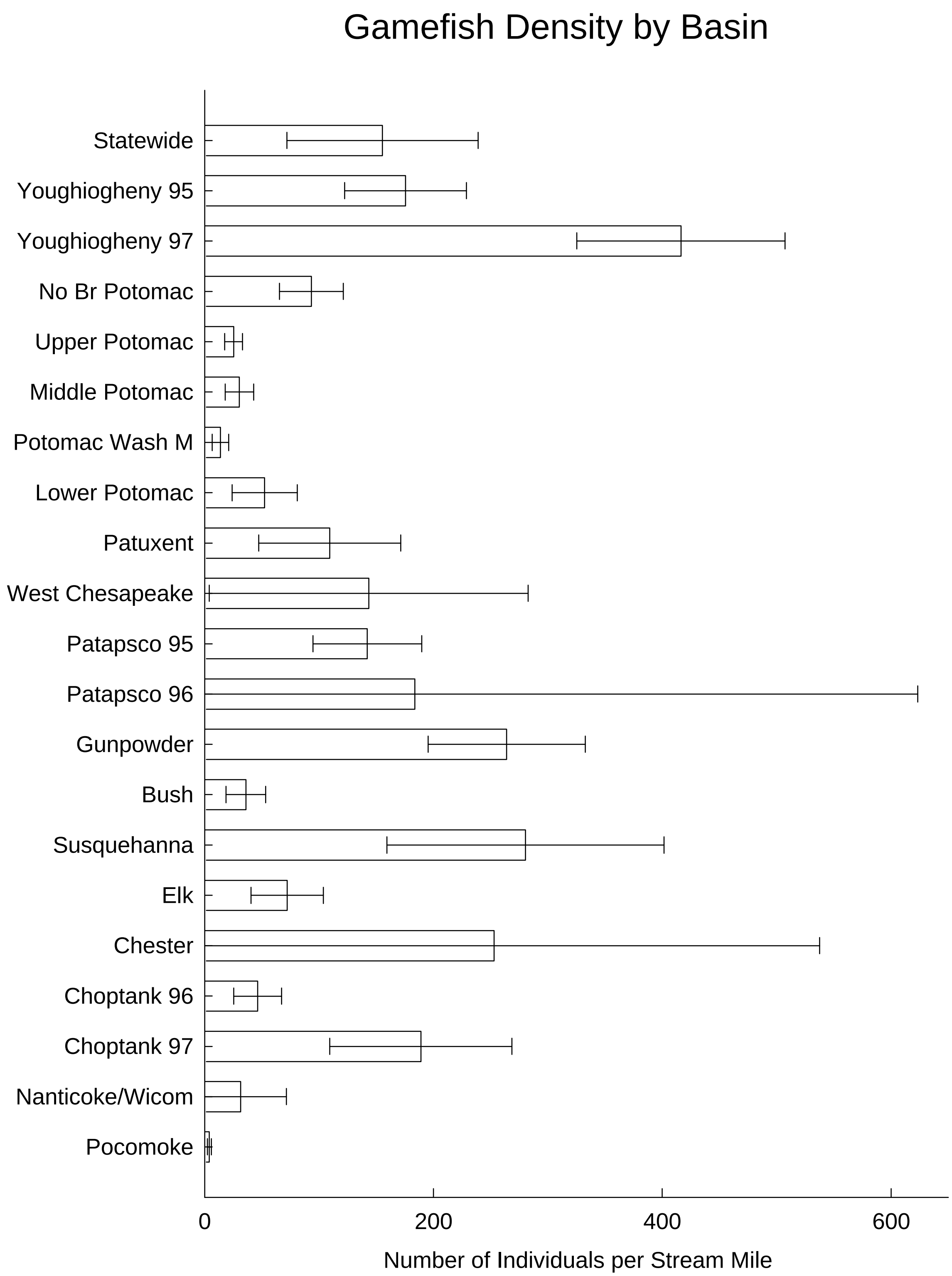


Figure 4-9. Total gamefish density (number of individuals per stream mile), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Density estimates are adjusted for capture efficiency.

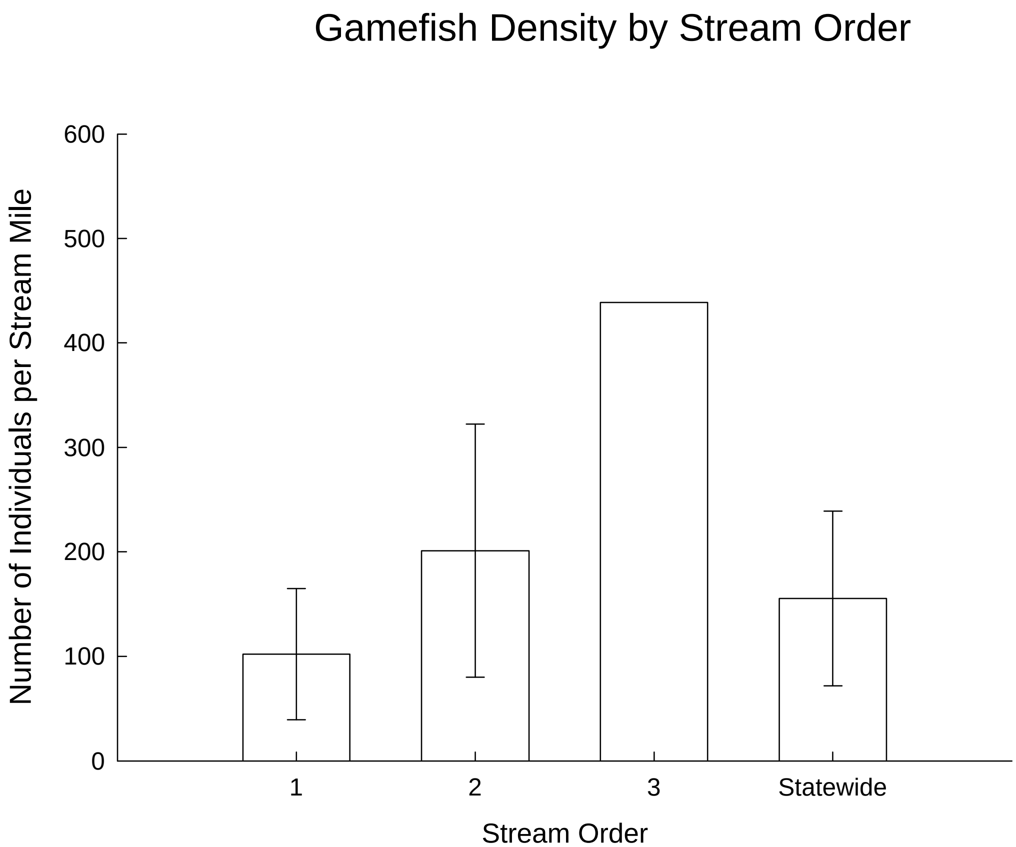


Figure 4-10. Total gamefish density (number of individuals per stream mile), by stream order for the 1995-1997 MBSS. Error bars signify ±1 standard error (lack of error bars indicate that variance is statistically undefined). Density estimates are adjusted for capture efficiency.

Using measured lengths of individual gamefish, separate estimates were made of the abundance of legal-sized or otherwise harvestable gamefish. Minimum sizes used to designate harvestable gamefish were the statewide size limits of 12” for largemouth and smallmouth bass, 14” for chain pickerel, and 18" for striped bass. Harvestable trout were defined as those 6” or greater. Across all basins, brook trout were estimated to be the most abundant harvestable-size gamefish in first- through third-order streams, followed by brown trout (Appendix E, Table E-3). Population estimates of harvestable-sized gamefish in low-order streams statewide were: 55,160 brook trout, 43,882 brown trout, 6,987 rainbow trout, 4,928 chain pickerel, and 4,530 largemouth bass, with smaller numbers of cutthroat trout and smallmouth bass. No harvestable size striped bass (a species abundant in tidal waters) were found in the streams surveyed. The abundance of harvestable-size gamefish was greatest in the Gunpowder basin, with an estimated 23,565 harvestable-size fish (Figure 4-12).

4.1.3 Individual Health of Fish

The health of stream fishes was assessed through the observation of specific anomalies on individual game and nongame fish. At each segment all gamefish and up to 100 individuals of each nongame fish species were examined for visible external anomalies. For gamefish, the anomalies present on each individual fish were recorded. For nongame fish, the number of fish of each species with each anomaly type was recorded. No differentiation was made between a fish with only one anomaly and one fish that had several (e.g., a fish that had both black spot and anchor worm was counted once in each of those categories). The numbers reported here assume that the maximum number of anomalies occurred (per fish). Therefore, the numbers may slightly underestimate the number of nongame fish with anomalies. Values were first summarized as the percentage of fish exhibiting anomalies (Table 4-5). Overall occurrence of anomalies was lower among gamefish (2%)

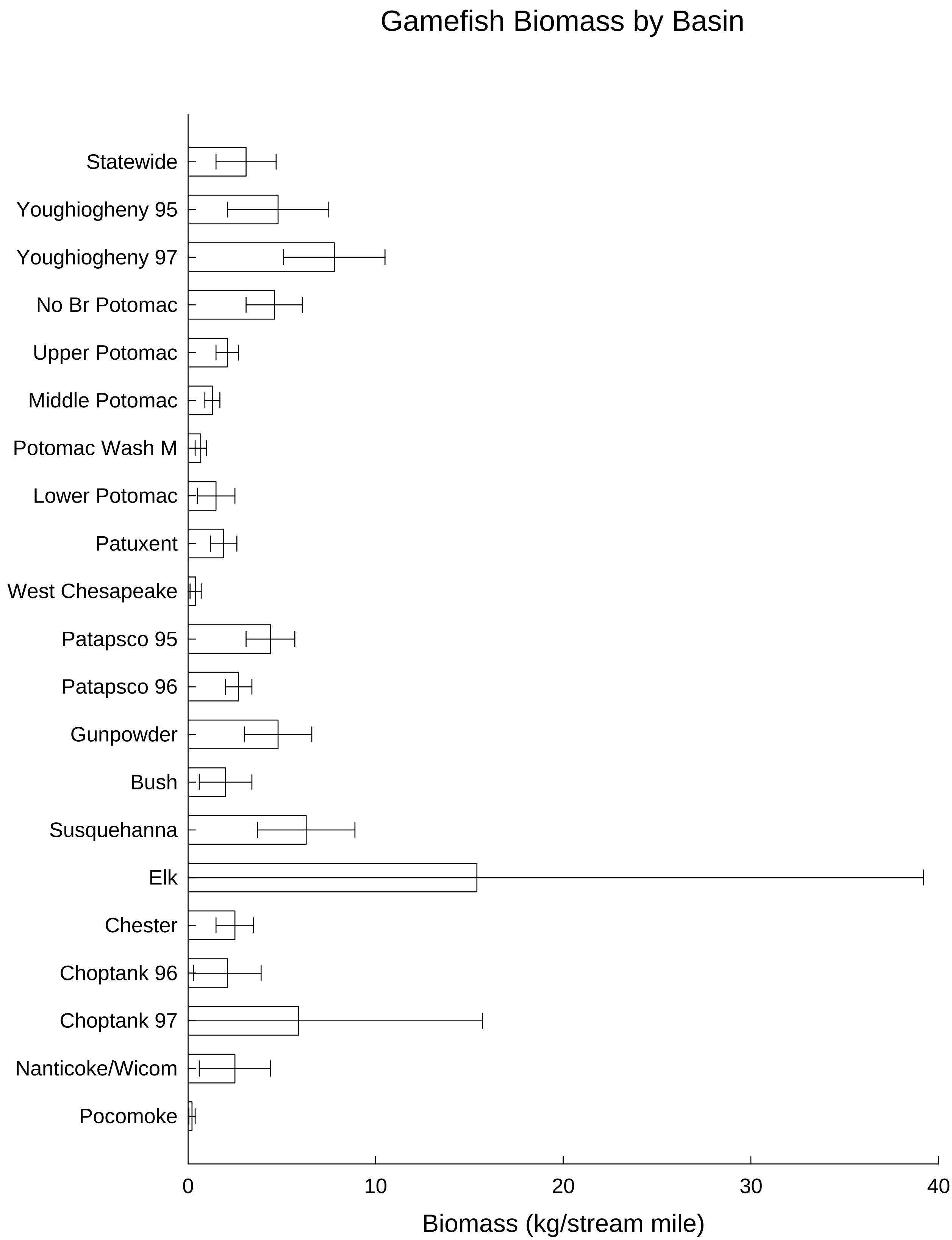


Figure 4-11. Gamefish biomass (kg per stream mile), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Biomass estimates are adjusted for capture efficiency.

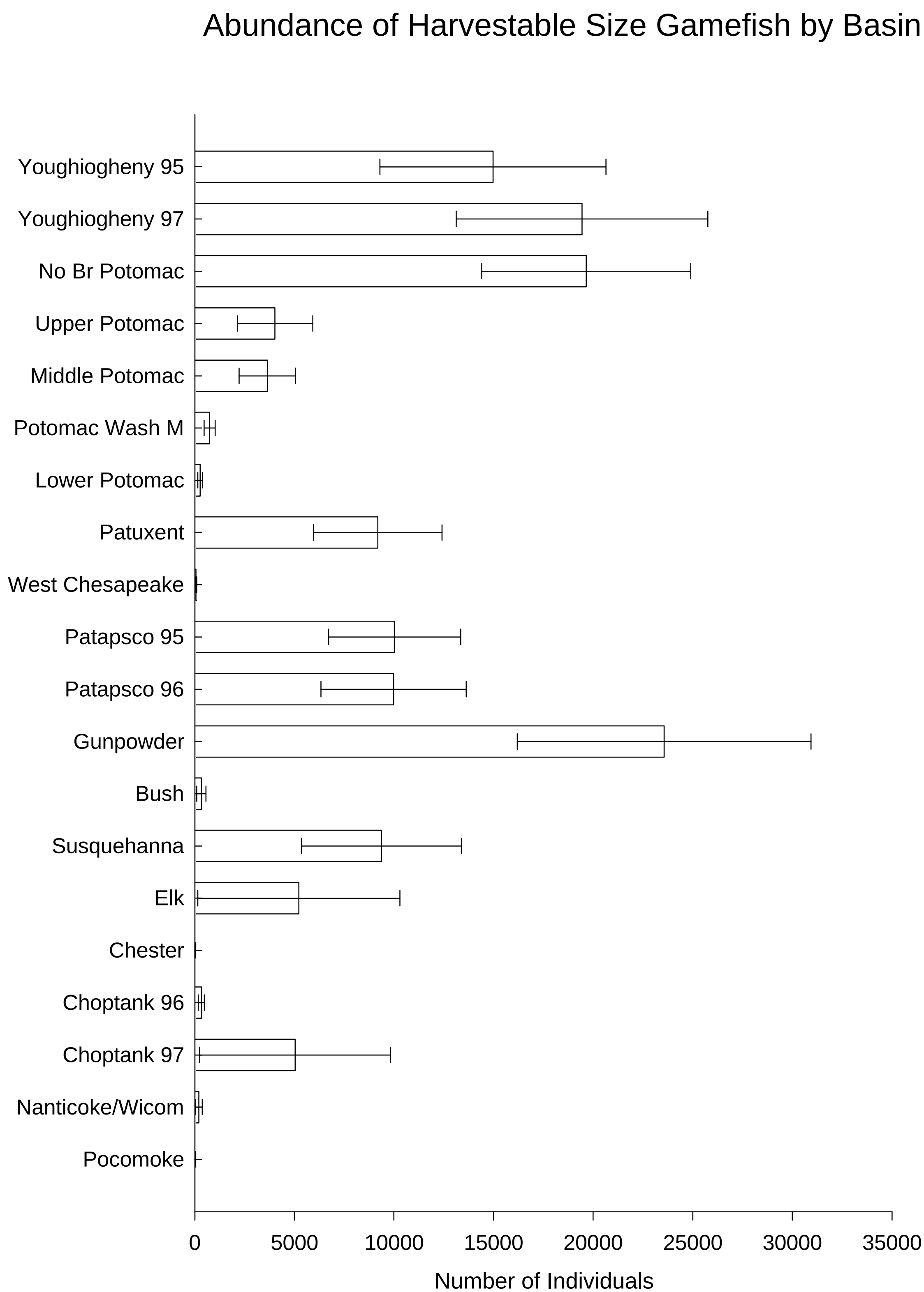


Figure 4-12. Estimates of the total abundance of harvestable size gamefish (number of individuals), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error. Abundance estimates are adjusted for capture efficiency.

Table 4-5. Occurrence of anomalies (percent of fish with anomalies) among game and nongame fish for basins sampled in the 1995-1997 MBSS. These estimates include all recorded anomaly types.

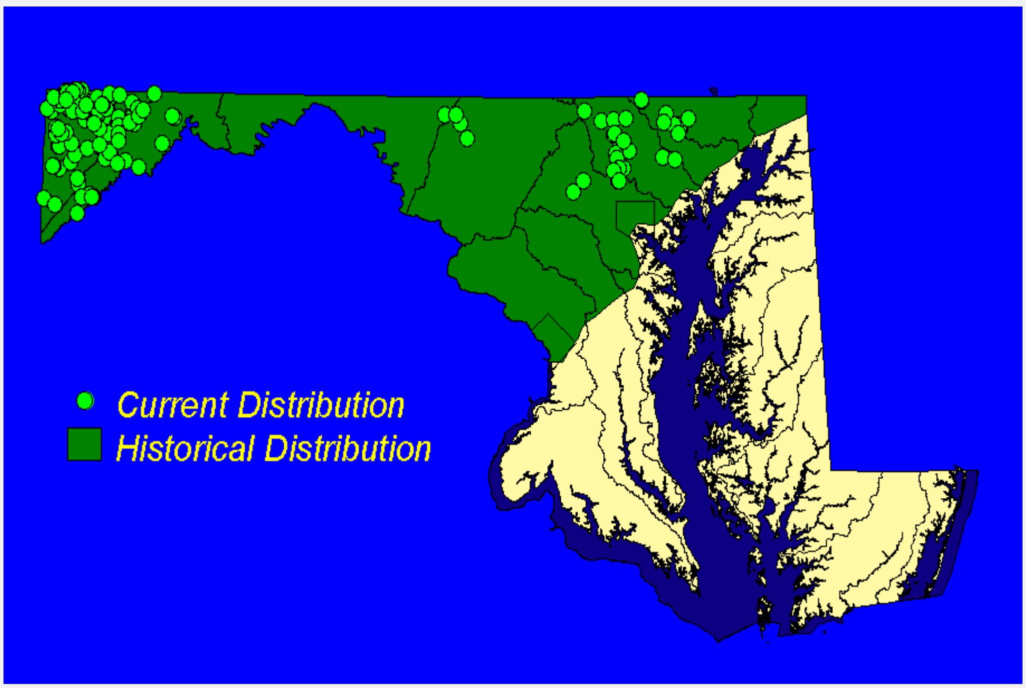
	Percent of Gamefish with Anomalies	**Standard Error**	**Percent of Nongame Fish with Anomalies**	**Standard Error**
Basin				
Youghiogheny 1995	0.9	0.6	5.9	0.7
Youghiogheny 1997	0.3	0.2	3.3	0.6
North Branch Potomac	4.3	2.1	11.8	1.5
Upper Potomac	11.3	3.3	9.8	0.9
Middle Potomac	6.0	1.5	9.1	0.8
Potomac Washington Metro	6.0	0.9	4.6	0.9
Lower Potomac	1.6	1.6	1.9	0.3
Patuxent	0.9	0.6	2.8	0.4
West Chesapeake	0.8	0.02	1.4	0.8
Patapsco 1995	0.9	0.5	5.1	0.7
Patapsco 1996	2.2	1.1	8.2	1.1
Gunpowder	0.1	0.1	5.3	0.5
Bush	8.1	3.2	9.4	2.6
Susquehanna	1.1	0.6	2.7	0.4
Elk	37.1	17.8	6.7	0.6
Chester	2.2	1.6	3.2	0.9
Choptank 1996	0.6	0.7	1.3	0.2
Choptank 1997	0.5	0.4	0.7	0.2
Nanticoke/Wicomico	0	0	0.9	0.3
Pocomoke	4.5	3.2	1.1	0.3
Stream Order				
1	1.7	2.4	4.1	0.4
2	1.1	1.0	6.4	1.1
3	4.4	2.1	6.9	1.2
Statewide	2.1	1.5	5.3	0

* Variance statistically undefined

Brook Trout - Past, Present, and Future

Results from the Survey indicate that between 200,000 and 400,000 brook trout now live in Maryland. This is a small fraction of the number thought to exist before European colonization. Based on the calculations described below, more than 2.9 million brook trout once existed in Maryland streams.

To estimate the size of the pre-European population, brook trout densities at MBSS sites most comparable to historical conditions (559 brook trout per stream mile) were extrapolated to the geographic area that likely approximates the historical distribution of brook trout (all of Maryland west of the Coastal Plain or 4,841 stream miles). The following four assumptions were used in this analysis:



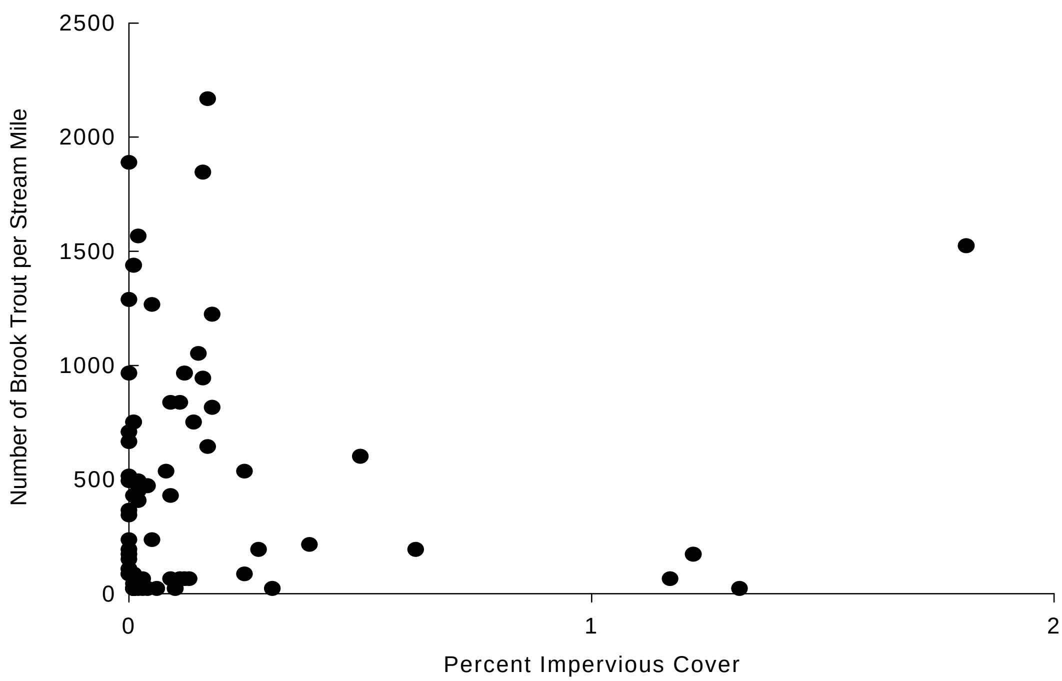
- Assumption 1 - Prior to European settlement, brook trout occurred only in first- through third-order streams. *It is possible that brook trout historically inhabited fourth-order streams that were more shaded than they are today. Therefore, the estimate of historical abundance may be conservative.*

- Assumption 2 - Small streams not included in the MBSS sample frame did not contain historical populations of brook trout. *It is almost certain that brook trout historically inhabited small streams not captured by the 1:250,000 scale reach file employed for the Survey. Therefore, the estimate of historical abundance may be conservative.*

- Assumption 3 - All streams west of the Coastal Plain contained populations of brook trout. *Because it is unlikely that brook trout were found in every watershed within these physiographic regions, the estimate of historical abundance may be an overestimate of the historical population size. On the other hand, brook trout may have historically extended into the Coastal Plain, especially near the transition zone with the Piedmont. Jabez Branch, a tributary to the Severn River, harbored what may have been a relic population of brook trout until they were extirpated in 1989. If at least some Coastal Plain streams had habitat suitable for brook trout, it would lessen the overestimate under this assumption.*

- Assumption 4 - The current mean brook trout density in non-degraded Maryland streams corresponds to the densities existing during the pre-European period. *This value is based on densities observed at sites rated as "good" or "not bad" during the1995-1997 MBSS Survey (see Roth et al. 1997, Appendix C for a definition of 'good' and 'not bad'). Since embeddedness in brook trout streams is almost certainly higher today (and productivity of forage lower) compared to pre-European conditions, the brook trout densities today may be considerably lower than the historical densities. Therefore, the estimate of historical abundance may be conservative.*

Even though considerable uncertainty is associated with the above assumptions, it is clear that the abundance of brook trout has declined dramatically from its historical levels. Although the reasons for the decrease in brook trout are many, one of the most important may be increases in water temperature. As trees were cleared for agriculture and housing, previously forested streams were exposed to direct sunlight as well as to heated water running off impervious surfaces like roads and rooftops. Today, fewer and fewer streams have temperature regimes suitable for brook trout, particularly in the eastern half of the State. The graph below dramatically illustrates that the majority of brook trout exist in watersheds with less than 0.5% impervious surface, and that none exist in watersheds with greater than 2% impervious surface. Other major threats to the continued existence of brook trout in Maryland include (1) silt from new construction and agriculture, (2) competition from non-native brown trout, (3) habitat loss from logging, (4) loss of forests along streams, (5) acid rain, and (6) global warming.



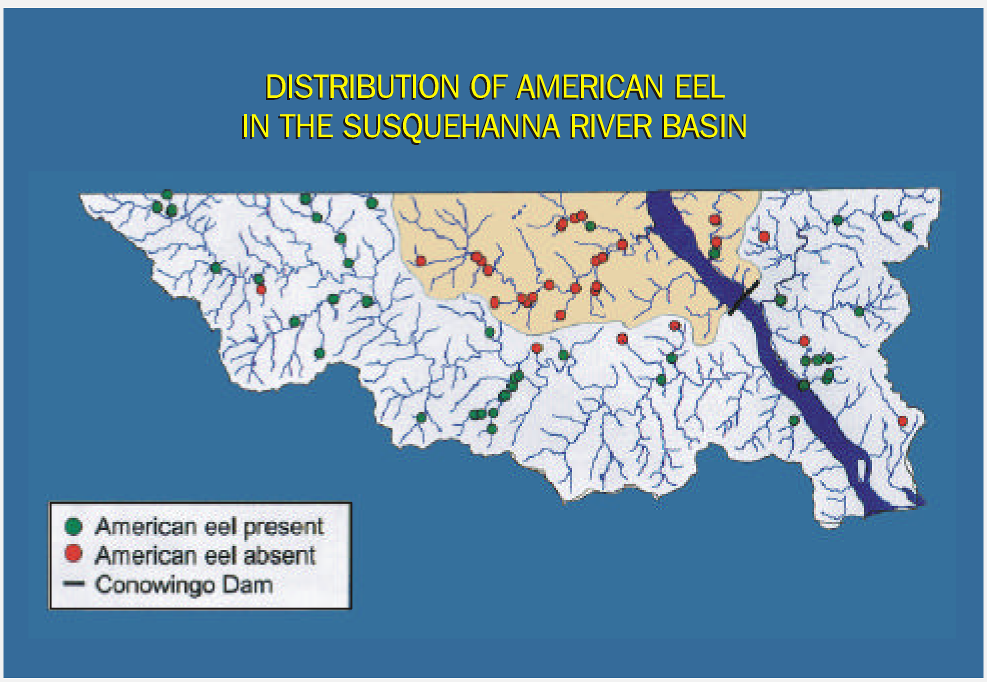
Relationship between watershed imperviousness and brook trout density at MBSS sites sampled during 1995-1997.

American Eel - Past, Present, and Future

The American eel has a life history unique among Maryland fish species. In contrast to anadromous fish (such as American shad) that spawn in Maryland's freshwater rivers and grow to maturity in the ocean, the catadromous eel spawns in the tropical Atlantic ocean and grows to maturity in estuarine and freshwater habitats. Juvenile eels (or elvers) must migrate upstream through estuaries, rivers, and streams to reach habitats that will support them (for 20 years or more) before reaching sexual maturity and migrating to their spawning area in the Sargasso Sea. European colonization of Maryland was accompanied by the construction of numerous small dams to supply water power for mills. Later, dams on larger streams and rivers were added for transportation, water supply, flood control, and hydroelectric projects. Today, the more than 1,000 man-made barriers to migratory fish in Maryland (Leasner, DNR, pers. comm.) have reduced access of American eel and other fish to their historical habitats.

It is likely that the American eel was abundant in virtually all the estuaries, rivers, streams, and lakes of Maryland and other coastal states prior to the colonization of North America. Since that time, the fate of eel stocks in Maryland streams has been similar to the fate of the brook trout. While brook trout populations have declined or disappeared as a result of sometimes subtle changes in the water and habitat quality, the more robust and resilient eel has declined as a result of the cumulative effect of pollution, heavy exploitation, and extensive and major changes to the habitats through which it migrates and in which it grows to maturity.

The most dramatic evidence for the impact of major dams on eel abundance can be found in the Susquehanna River basin. Prior to completion of four mainstem dams on the lower Susquehanna (the last, Conowingo Dam, was built in 1928), eels were common throughout the Susquehanna basin and were popular with anglers in Pennsylvania lakes (PCF 1897). Annual harvests of eels in the Susquehanna were nearly 1 million pounds at that time (Foster 1995). For many decades, there have been no recreational or commercial harvests of this species in Pennsylvania. MBSS data suggest that the mainstem dams have been a major factor in this decline by blocking the upstream migration of juvenile eels.



The MBSS sampled 37 sites within the Maryland portion of the Susquehanna River basin. Of these sites, 11 were on Susquehanna tributaries that emptied into Conowingo Pond upstream of the dam. The remaining 26 sites were located on tributaries, such as Deer Creek, that empty into the river below the dam. At the 11 above-dam sites, only a single eel was taken during sampling. In contrast, eels were captured at 25 of the 26 sites sampled on the below-dam tributaries; the average number of eels taken per station was 37, with a high of 150 at one station on Basin Run. While no fisheries survey data are available for Pennsylvania and New York rivers and streams in the Susquehanna watershed, it is reasonable to conclude from the MBSS and anecdotal fisheries data that the watershed is essentially devoid of eels at the present time.

MBSS data can be used to estimate the probable loss in eel production attributed to mainstem barriers in the Susquehanna basin. Mean eel density was calculated based on the densities observed during the 1995-1997 MBSS, with first-, second-, and third-order stream sites weighted by their relative abundance in the Maryland portion of the Susquehanna basin. If we assume that the mean density of American eel in the Susquehanna basin below Conowingo Dam (approximately 500 per stream mile) is representative of the potential mean density of eels in all streams in the basin (26,064 miles), we estimate that the decline in abundance could be as great as 13 million eels. This estimate assumes no production of eels in any of the lakes and ponds in the watershed, and also ignores the fact that the density of eels in fourth-order and larger streams common in the watershed is greater than the density in third-order and smaller streams, as was found in MBSS supplemental survey sampling in some larger streams. Thus, it is likely that this is a conservative estimate of eel losses.

A recent report documents an apparent continent-wide decline in American eel abundance since the early 1980s (Richkus and Whalen 1999). Such a decline is of great significance, since all eels found in North and South America are produced by a single spawning stock. Contributing factors to this decline have been hypothesized to include changes in ocean currents, pollution, excessive exploitation, hydroelectric facility impacts, migration barriers, and other types of habitat alteration. While no specific causative factor has been identified to date, any measures that would enhance the production and survival of eels throughout their range would contribute to stemming or reversing the apparent decline. MBSS findings suggest that providing for the successful upstream passage of juvenile eels at mainstem dams on the Susquehanna River is such a measure.

than nongame fish (5%) and tended to increase with stream size. Using the less conservative estimate that each fish had only one type of anomaly, 12% of nongame fish would have anomalies. Values in Table 4-5 represent all anomalies recorded, including hooking injuries, cuts, ich, and the presence of visible parasites such as black spot and leeches. Statewide, the occurrence of each anomaly type in nongame fish was low, with almost every type found in less than 0.1% of fish (Table 4-6). Only black spot (8.2%) and red spot (2.5%) were found in greater than 1% of fish statewide. The same results were observed in the individual basins. While more than five anomaly types occurred in every basin sampled, only black spot, eye cloudiness, and red spot occurred in more than 1% of nongame fish in any of the basins sampled. Among gamefish, these numbers were even lower (Table 4-7). Statewide, 18 of the 28 anomalies examined for were found, with only black spot occurring in more than 1% of gamefish. For each individual basin, the occurrence of gamefish with anomalies was also low, with only nine basins containing greater than 1.0% of fish with anomalies. The Nanticoke/Wicomico basin did not contain any gamefish with anomalies, while the greatest percentage of gamefish with anomalies occurred in the Elk basin. This result may be a result of small sample size, as only 18 sites were sampled in the Elk and only nine gamefish were caught there.

Particularly for nongame species, the above values to a large degree reflect the frequent occurrence of blackspot, a trematode parasite that is not especially indicative of impaired fish health. Because blackspot is fairly common, the incidence of a subset of anomalies, excluding blackspot and other parasites, injuries, and ich, was estimated. This subset included only pathological anomalies, which fell into three groups: ocular, skeletal, and skin anomalies (Table 4-8). The occurrence of these pathological anomalies is a potential indication of anthropogenic stress to fish communities.

Table 4-6. Percent occurrence of anomaly types in nongame fish for the 1995-1997 MBSS. Shading indicates anomaly occurs in greater than 1.0% of fish.

	Statewide	Youghiogheny 1995	Youghiogheny 1997	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco 1995	Patapsco 1996	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank 1996	Choptank 1997	Nanticoke/Wicomico	Pocomoke
Swelling of the Anus	<0.1				<0.1			<0.1			<0.1		<0.1								
Anchor Worm	<0.1	0.5		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1						<0.1	<0.1		<0.1	<0.1		
Black Spot	8.2	10.0	4.5	15.0	15.4	15.4	4.6	0.6	2.4	0.2	8.8	14.0	8.8	19.8	4.6	16.6	3.6	0.4	<0.1	<0.1	<0.1
Body Shape	<0.1	<0.1				<0.1		<0.1		<0.1	<0.1	<0.1			<0.1		<0.1				
Cataract	<0.1					<0.1	<0.1		<0.1		<0.1			<0.1	<0.1					<0.1	
Cut	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1				<0.1				<0.1		0.3
Discoloration	<0.1	<0.1											<0.1		<0.1			<0.1	<0.1		<0.1
Deformities of the Mandible	<0.1	<0.1			<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2
Deformities of the Vertebrate Column	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1		<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1			<0.1
Eye Cloudiness	<0.1					<0.1		<0.1		1.0	<0.1	<0.1	<0.1		<0.1		<0.1	<0.1	0.7	0.3	<0.1
Eye Hemmorrhage	<0.1				<0.1			<0.1			<0.1				<0.1				<0.1		
Visible External Parasites	0.2	0.3		0.3	0.2	<0.1	<0.1	0.7	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	0.2	<0.1	0.2	<0.1	<0.1	0.2	<0.1
Fin Deformed or Missing	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1			<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Fin Erosion	0.3	0.3	<0.1	<0.1	0.4	0.4	0.2	0.5	0.3	<0.1	0.4	0.4	<0.1		0.2	<0.1	<0.1	0.2	<0.1	<0.1	0.3
Fungus	<0.1	<0.1		<0.1	<0.1	<0.1		<0.1		<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1		
Growths/Cysts	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1	0.9		<0.1	<0.1
Hooking Injury	<0.1	<0.1			<0.1																
Hemorrhaging	0.2	0.2		0.2	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	0.7	0.4	<0.1	<0.1	0.7	0.2	<0.1	<0.1	0.4
Ich	<0.1											<0.1									
Leeches	<0.1	<0.1		0.3	0.6	0.2	<0.1	0.2	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1
Eye Missing	<0.1	<0.1				<0.1		<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1		<0.1
Depression Into the Orbits	<0.1				<0.1				<0.1		<0.1				<0.1						
Other	<0.1	<0.1				<0.1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1		<0.1		<0.1	<0.1	<0.1
Exopthalmia	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1		<0.1		<0.1	<0.1	<0.1
Red Spot	2.5	3.3	1.1	8.3	6.3	4.4	2.9	1.2	2.0		2.0	2.6	4.1	1.2	1.8	0.7					
Raised Scales	<0.1	<0.1			<0.1						<0.1		<0.1								
Scale Deformities	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1			<0.1						
Ulcerations/Lesions	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	0.3	<0.1		<0.1	<0.1	<0.1	<0.1	0.3	<0.1	0.2	0.4	0.3	0.2	0.2

Table 4-7. Percent occurrence of anomaly types in gamefish for the 1995-1997 MBSS. Shading indicates anomaly occurs in greater than 1.0% of fish.

	Statewide	Youghiogheny 1995	Youghiogheny 1997	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington	Lower Potomac	Patuxent	West Chesapeake	Patapsco 1995	Patapsco 1996	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank 1996	Choptank 1997	Nanticoke/Wicomico	Pocomoke
Swelling of the Anus																					
Anchor Worm	<0.1					0.6	1.4														
Black Spot	1.0			<0.1	2.8	3.3	0.8		<0.1		0.3	1.2	8.1	0.2	30.1	0.9	0.6				
Body Shape																					
Cataract	<0.1	0.3										0.3									
Cut	0.2	0.3	<0.1	0.3	0.9	0.5	2.3								<0.1	3.5					
Discoloration																					
Deformities of the Mandible	<0.1			<0.1	0.5																
Deformities of the Vertebrate Column	<0.1	<0.1						0.3													
Eye Cloudiness	<0.1				0.5						<0.1	0.3									
Eye Hemmorrhage	<0.1														0.5						
Visible External Parasites	<0.1			<0.1	0.9	0.8		0.8	0.2		0.2										
Fin Deformed or Missing	0.2		0.2	1.9						0.3											
Fin Erosion	0.2	0.2		0.8	0.8	0.6			0.3	0.5	0.3	0.3			<0.1		1.4				2.2
Fungus	<0.1						0.8												0.5		
Growths/Cysts	<0.1															3.5					
Hooking Injury	<0.1	<0.1		0.5	2.2		0.8														
Hemorrhaging	<0.1							0.3													
Ich																					
Leeches	<0.1			0.3	2.8	0.3															
Eye Missing																					
Depression Into the Orbits																					
Other	<0.1														<0.1						
Exopthalmia																					
Red Spot																					
Raised Scales																					
Scale Deformities																					
Ulcerations/Lesions	<0.1							0.3				<0.1	<0.1								2.2

Table 4-8.	Three general categories of pathological anomalies observed in fish, with specific types of anomalies that fall under each
	Ocular Anomalies
	Eye Cloudiness Eye Hemorrhage Exopthalmia (pop eye) Depression into the Orbits Eye Missing Cataract
	Skin Anomalies
	Discoloration Hemorrhaging Fin Cloudiness Raised Scales Growths/Cysts Ulcerations/Lesions Fin Erosion Swelling of the Anus Scale Deformities Fin Deformed or Missing
	Skeletal Deformities
	Deformities of the Vertebral Column Deformities of the Mandible Body Shape

Overall, pathological anomalies were observed infrequently in both gamefish (0.8%) and nongame fish (0.5%). A variety of skin anomalies were found on about 0.7% of the individual gamefish, while ocular and skeletal anomalies were observed on less than 0.1% of the gamefish (Figure 4-13). Pathological anomalies were slightly more common in gamefish of third-order streams (2.0%), perhaps indicating (1) a greater influence of point source discharges in larger streams or (2) the cumulative effects from upstream sources. Larger, older fish usually found in third-order streams may also have more anomalies than juveniles collected in smaller headwater streams. Pathological anomalies on gamefish were most common in the Elk basin (Table 4-9, Figure 4-14), although this estimate may again be attributed to small sample size. Among nongame fish, pathological anomalies occurred infrequently (Table 4-10, Figure 4-15). Statewide, less than 0.5% of nongame fish had pathological anomalies.

Another way to summarize the occurrence of anomalies in fish is to estimate the percentage of stream miles having fish with certain anomaly types. For all fish, pathological anomalies occurred in 44% of stream miles. The Choptank basin had the greatest percentage of stream miles (83%) with fish exhibiting pathological anomalies. Skin anomalies made up the greatest percentage of these anomalies, occurring at 40% of stream miles statewide (Figure 4-16).

For gamefish, the overall occurrence of pathological anomalies was not widespread. Based on 1995-97 MBSS sampling, only about 2% of stream miles had gamefish with any type of pathological anomaly (Table 4-11, Figure 4-17). Most of these anomalies were skin anomalies, with the highest percentage occurring in the Elk basin (11%). Less than 1% of stream miles had gamefish with ocular or skeletal anomalies. Estimates are based on data from all sites sampled during the summer index period.

Among nongame fish, pathological abnormalites were observed more frequently (Table 4-12, Figure 4-18). An estimated 40% of stream miles had nongame fish with skin anomalies. Skin anomalies were observed in an estimated 73% of third-order streams, 55% of second-order streams, and 31% of first-order streams. The greater extent of anomalies in second- and third-order streams could reflect

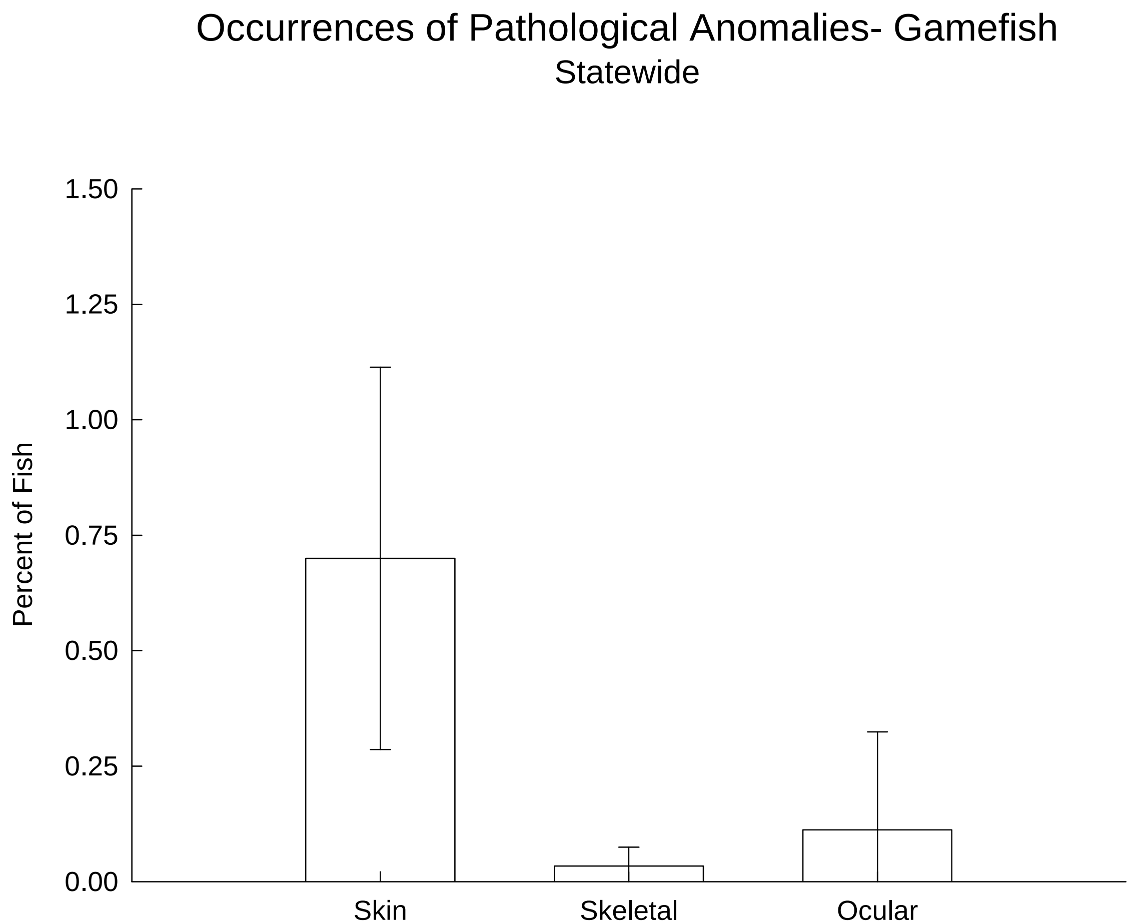


Figure 4-13. Percentage of fish with each type of pathological anomaly (skin, skeletal, or ocular), statewide for the 1995-1997 MBSS. Error bars signify ±1 standard error.

more degraded water quality and the presence of larger, older individuals in larger streams. Skin anomalies in nongame fish were most prevalent in the Choptank basin (1996 sampling), where occurrence was estimated at 80% of stream miles. In contrast, the Youghiogheny basin (1997 sampling) had only 5% of stream miles with nongame fish exhibiting skin anomalies. Ocular anomalies in nongame fish occurred less often, in about 9% of stream miles overall. Again, estimates were highest for third-order (19%) and second-order (14%) stream miles. Ocular anomalies were most prevalent in nongame fish in the Susquehanna basin (28% of stream miles). Skeletal deformities in nongame fish were estimated to occur in about 7% of stream miles statewide, and were slightly higher in second and third-order streams. The Pocomoke basin had the highest incidence of skeletal anomalies in nongame fish (29% of stream miles).

Some programs have successfully employed the prevalence of anomalies as one component of a fish Index of Biotic Integrity (IBI) (e.g., Ohio EPA 1987). However, in developing a fish IBI for Maryland, the incidence of anomalies (total or pathological) was ineffective in detecting differences in site condition and was therefore not included in the fish IBI for Maryland (Roth et al. 1998).

Table 4-9. Occurrence of pathological anomalies among gamefish (percent of fish with pathological anomalies) for basins sampled in the1995-1997 MBSS. Estimates include the anomaly types listed in Table 4-8.

	Percent of gamefish with pathological anomalies	**Standard Error**	**Percent of gamefish with skin anomalies**	**Standard Error**	**Percent of gamefish with skeletal anomalies**	**Standard Error**	**Percent of gamefish with ocular anomalies**	**Standard Error**
Basin								
Youghiogheny 1995	0.52	0.32	0.25	0.18	0.00	0.00	0.27	0.26
Youghiogheny 1997	0.25	0.16	0.25	0.16	0.04	0.05	0.00	0.00
North Branch Potomac	2.90	1.84	2.90	1.84	0.14	0.14	0.00	0.00
Upper Potomac	2.22	1.06	1.30	0.94	0.46	0.47	0.46	0.42
Middle Potomac	1.10	0.56	1.10	0.56	0.00	0.00	0.00	0.00
Potomac Washington Metro	0.77	0.78	0.77	0.78	0.00	0.00	0.00	0.00
Lower Potomac	0.81	0.78	0.54	0.52	0.27	0.26	0.00	0.00
Patuxent	0.25	0.15	0.25	0.15	0.00	0.00	0.00	0.00
West Chesapeake	0.81	0.02	0.81	0.02	0.00	0.00	0.00	0.00
Patapsco 1995	0.40	0.26	0.30	0.20	0.00	0.00	0.10	0.10
Patapsco 1996	0.99	0.47	0.44	0.32	0.00	0.00	0.55	0.35
Gunpowder	0.06	0.07	0.06	0.07	0.00	0.00	0.00	0.00
Bush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Susquehanna	0.67	0.52	0.14	0.11	0.00	0.00	0.53	0.50
Elk	10.49	6.63	10.49	6.63	0.00	0.00	0.00	0.00
Chester	1.39	1.23	1.39	1.23	0.00	0.00	0.00	0.00
Choptank 1996	0.64	0.72	0.64	0.72	0.00	0.00	0.00	0.00
Choptank 1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nanticoke/Wicomico	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pocomoke	4.49	3.21	4.49	3.21	0.00	0.00	0.00	0.00
Stream Order								
1	0.58	0.86	0.48	0.77	0.00	0.00	0.10	0.24
2	0.34	0.36	0.23	0.27	0.00	0.00	0.11	0.43
3	2.00	1.22	1.78	1.10	0.15	0.23	0.14	0.23
Statewide	0.83	0.56	0.70	0.41	0.03	0.04	0.11	0.21

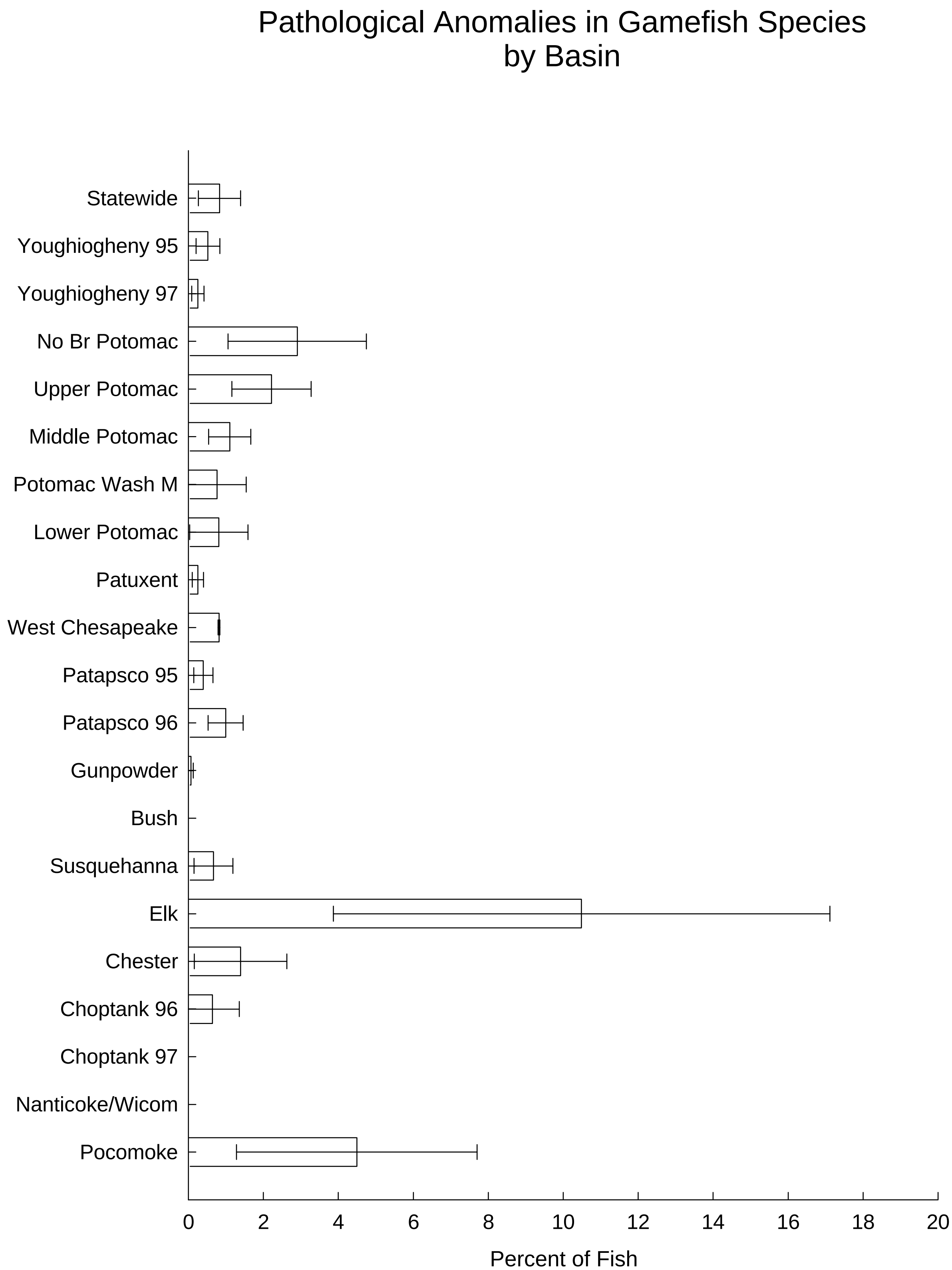


Figure 4-14. Occurrence of pathological anomalies in gamefish (percent of individual gamefish with pathological anomalies), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

Table 4-10. Occurrence of pathological anomalies among nongame fish (percent of nongame fish with pathological anomalies) for basins sampled in the 1995-1997 MBSS. Estimates include the anomaly types listed in Table 4-8.

	Percent of nongame fish with pathological anomalies	**Standard Error**
Basin		
Youghiogheny 1995	0.53	0.12
Youghiogheny 1997	0.10	0.05
North Branch Potomac	0.27	0.08
Upper Potomac	0.38	0.10
Middle Potomac	0.31	0.04
Potomac Washington Metro	0.33	0.09
Lower Potomac	0.61	0.11
Patuxent	0.30	0.07
West Chesapeake	1.14	0.74
Patapsco 1995	0.51	0.10
Patapsco 1996	0.44	0.07
Gunpowder	0.50	0.17
Bush	0.30	0.10
Susquehanna	0.59	0.15
Elk	0.36	0.14
Chester	0.98	0.39
Choptank 1996	1.09	0.24
Choptank 1997	0.58	0.19
Nanticoke/Wicomico	0.79	0.32
Pocomoke	0.84	0.30
Stream Order		
1	0.43	0.22
2	0.47	0.13
3	0.60	0.26
Statewide	0.47	0.10

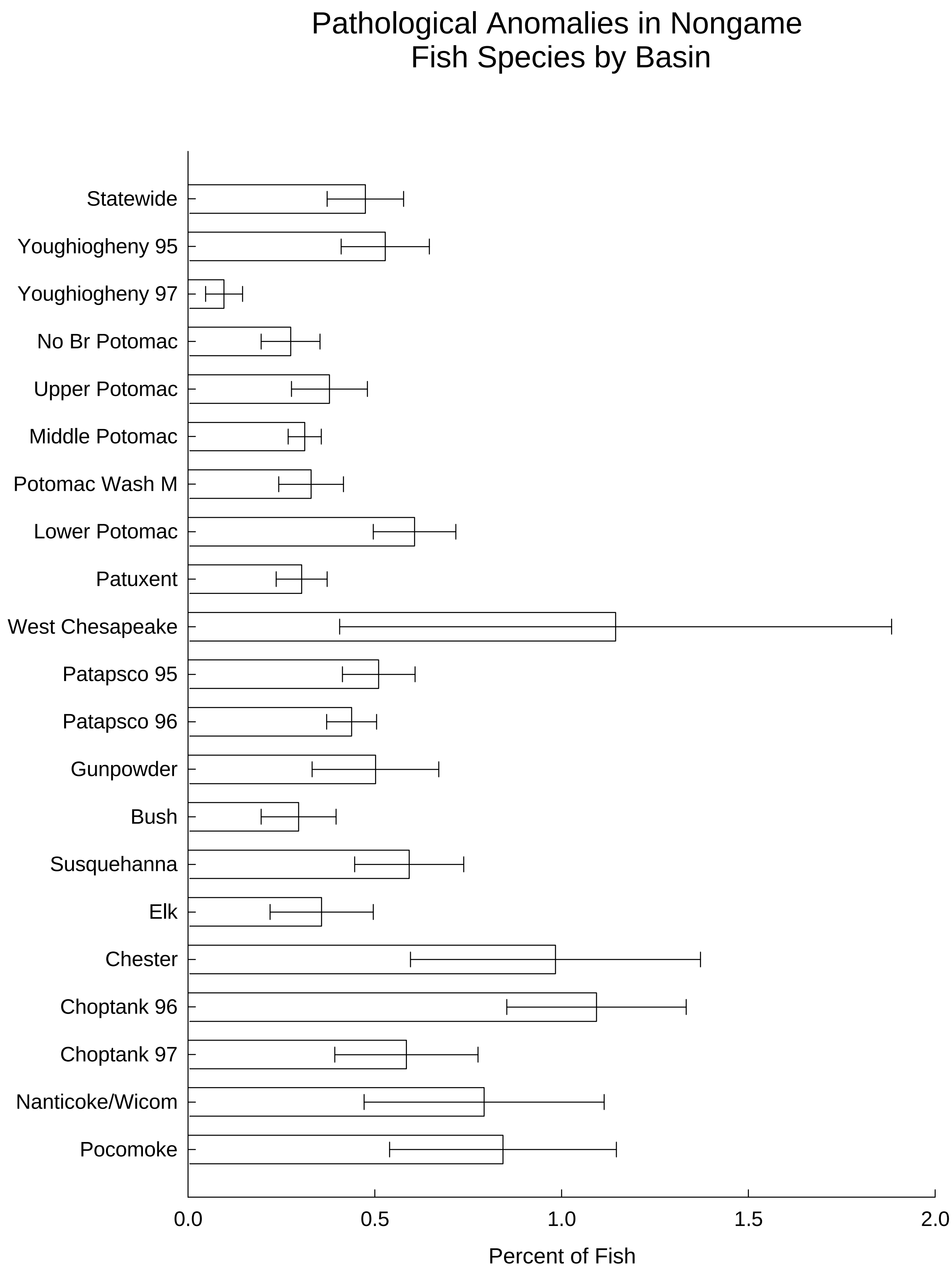


Figure 4-15. Occurrence of pathological anomalies in nongame fish (percent of nongame fish with pathological anomalies), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

Extent of Occurrence of Pathological Anomalies- All Fish

Statewide

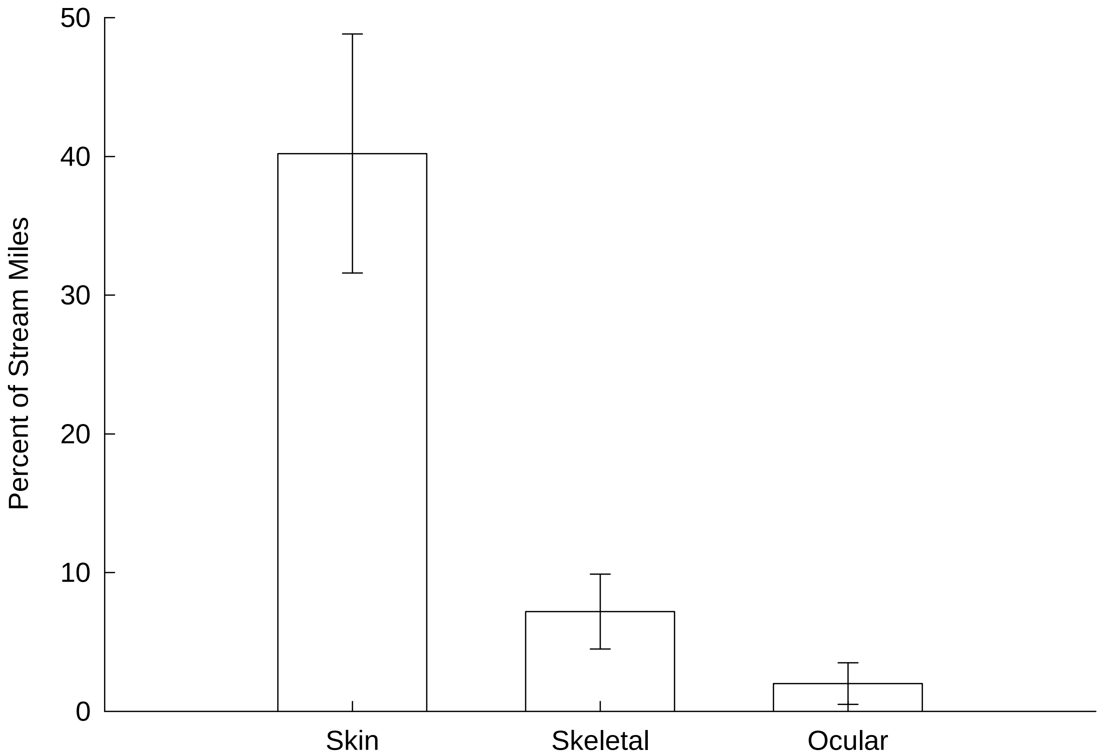


Figure 4-16. Percentage of stream miles containing fish with each type of pathological anomaly (skin, skeletal or ocular), statewide for the 1995-1997 MBSS. Error bars signify ±1 standard error.

Table 4-11. Percentage of stream miles having gamefish with each of three pathological anomaly types, for basins sampled in the 1995-1997 MBSS

	Skin Anomalies		**Ocular Anomalies**		**Skeletal Anomalies**	
	Mean	**Standard Error**	**Mean**	**Standard Error**	**Mean**	**Standard Error**
Basin						
Youghiogheny 1995	1.4	1.0	1.5	1.5	0.0	0.0
Youghiogheny 1997	3.3	1.9	0.0	0.0	0.9	0.9
North Branch Potomac	6.3	1.8	0.0	0.0	0.7	0.7
Upper Potomac	1.4	1.0	0.5	0.5	0.5	0.5
Middle Potomac	1.3	0.6	0.0	0.0	0.0	0.0
Potomac Washington Metro	0.5	0.5	0.0	0.0	0.0	0.0
Lower Potomac	0.6	0.6	0.0	0.0	0.6	0.6
Patuxent	0.9	0.5	0.0	0.0	0.0	0.0
West Chesapeake	1.5	1.5	0.0	0.0	0.0	0.0
Patapsco 1995	1.8	1.3	0.6	0.6	0.0	0.0
Patapsco 1996	0.9	0.6	1.8	1.1	0.0	0.0
Gunpowder	0.7	0.7	0.0	0.0	0.0	0.0
Bush	0.0	0.0	0.0	0.0	0.0	0.0
Susquehanna	1.7	1.2	5.9	5.9	0.0	0.0
Elk	10.5	10.5	0.0	0.0	0.0	0.0
Chester	5.9	5.6	0.0	0.0	0.0	0.0
Choptank 1996	1.1	1.1	0.0	0.0	0.0	0.0
Choptank 1997	0.0	0.0	0.0	0.0	0.0	0.0
Nanticoke/Wicomico	0.0	0.0	0.0	0.0	0.0	0.0
Pocomoke	0.9	0.6	0.0	0.0	0.0	0.0
Stream Order						
1	0.4	0.6	0.3	0.7	0.0	0.0
2	1.1	2.2	0.6	2.1	0.0	0.0
3	11.9	3.9	1.3	2.4	1.6	2.2
Statewide	1.7	0.7	0.5	0.7	0.2	0.2

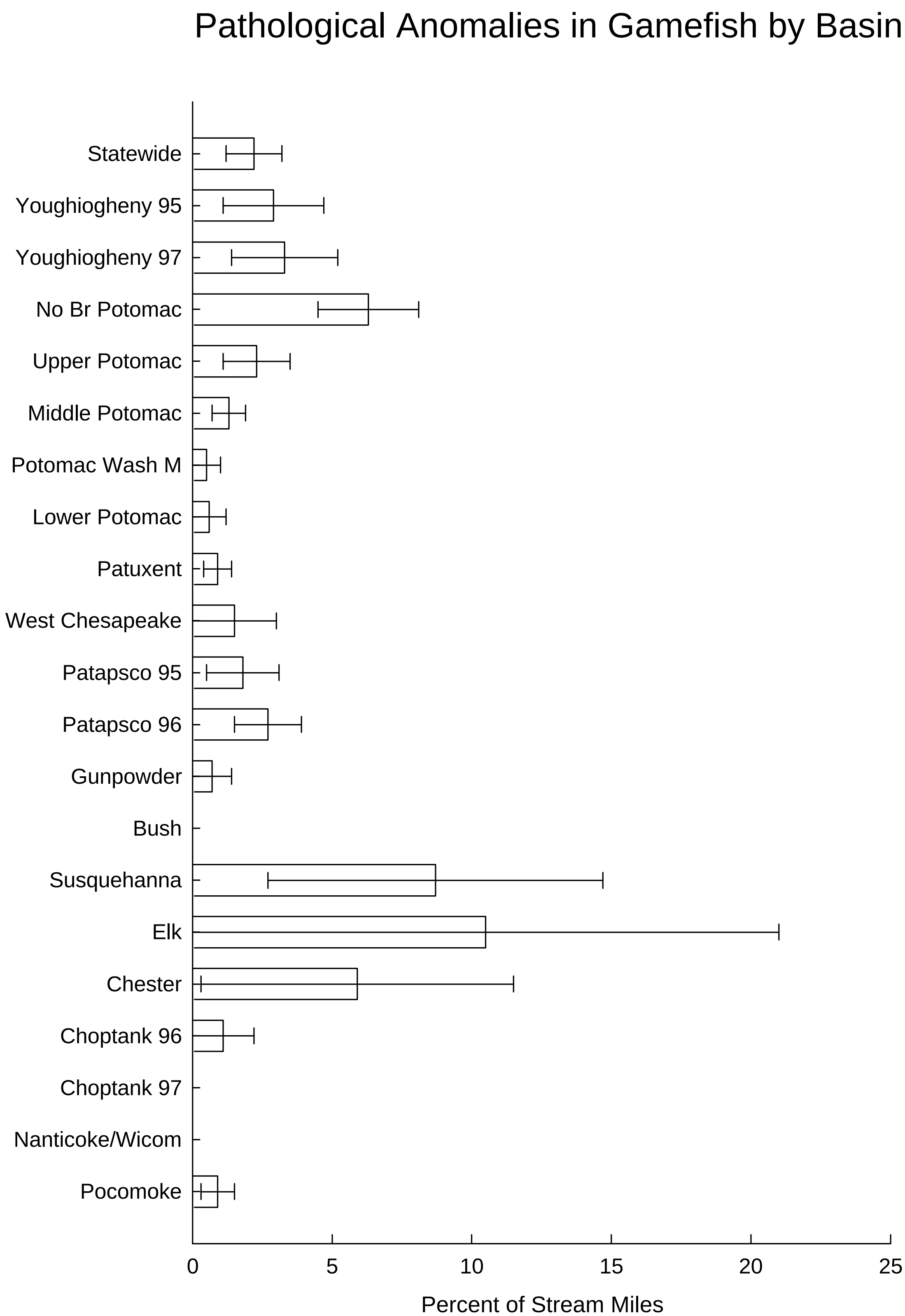


Figure 4-17. Percentage of stream miles with gamefish species having pathological anomalies, statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

Table 4-12. Percentage of stream miles having nongame fish with each of three pathological anomaly types, for basins sampled in the 1995-1997 MBSS

	Skin Anomalies		Ocular Anomalies		Skeletal Anomalies	
	Mean	**Standard Error**	**Mean**	**Standard Error**	**Mean**	**Standard Error**
Basin						
Youghiogheny 1995	48.2	12.4	3.0	2.1	14.9	8.7
Youghiogheny 1997	4.8	2.5	0.0	0.0	1.5	1.5
North Branch Potomac	14.3	3.5	0.0	0.0	2.0	1.5
Upper Potomac	26.4	5.6	3.3	1.7	8.6	4.8
Middle Potomac	39.4	5.8	13.2	3.6	4.8	2.5
Potomac Washington Metro	33.4	7.3	1.3	1.0	0.0	0.0
Lower Potomac	62.6	10.7	22.3	7.7	12.8	5.8
Patuxent	33.8	6.3	5.1	3.2	2.5	2.3
West Chesapeake	9.9	7.9	10.9	8.0	3.6	2.3
Patapsco 1995	56.9	8.4	14.3	3.2	9.9	4.2
Patapsco 1996	46.3	8.2	8.1	3.8	9.5	3.8
Gunpowder	45.1	8.9	10.1	5.7	10.9	5.8
Bush	64.4	16.8	8.1	3.8	2.2	2.2
Susquehanna	62.8	12.1	27.7	10.0	9.1	6.3
Elk	53.1	17.3	2.4	5.4	7.2	4.3
Chester	51.5	12.9	9.0	3.7	9.6	6.1
Choptank 1996	79.5	19.9	2.2	1.5	14.0	11.2
Choptank 1997	20.2	11.2	25.1	11.4	0.8	0.8
Nanticoke/Wicomico	27.7	13.8	19.4	11.7	8.4	8.4
Pocomoke	28.7	13.5	22.8	13.3	29.2	15.6
Stream Order						
1	30.6	11.1	6.4	3.4	6.3	4.1
2	54.8	8.8	14.3	8	8.7	3.3
3	72.7	16.8	18.6	11.6	9.2	7.3
Statewide	39.7	9.1	9.2	2.7	7.1	2.8

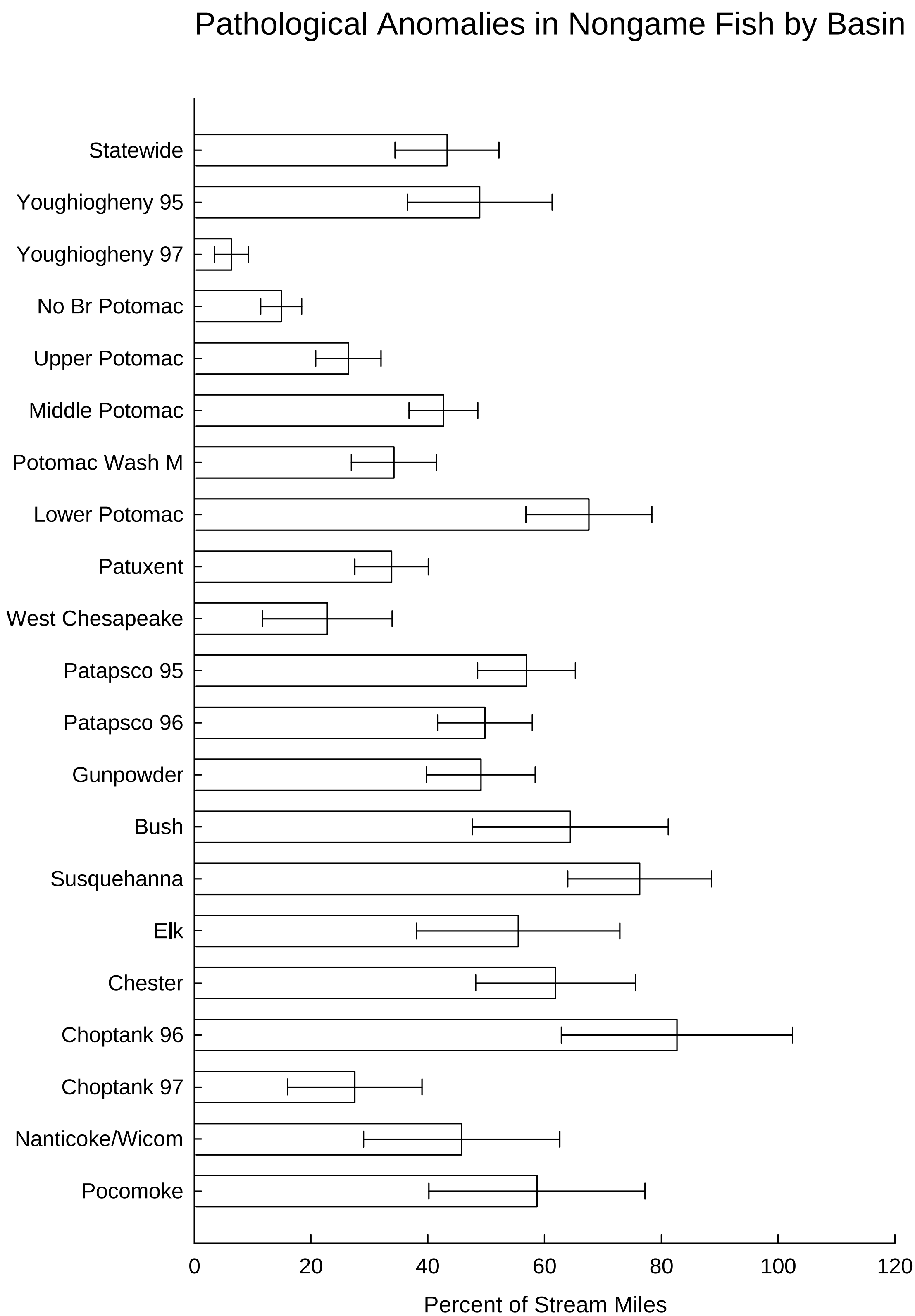


Figure 4-18. Percentage of stream miles with nongame fish species having pathological anomalies, statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

4.2 BENTHIC MACROINVERTEBRATES

Three hundred forty-six (346) genera within 112 families were collected during 1995-1997 MBSS sampling at 955 sites (Appendix C, Table C-3). Among all basins, the Lower Potomac had the highest total number of taxa combined across sites (190), while the Bush and the Elk both had the lowest (83) (Figure 4-19). In general, basins on the Coastal Plain (e.g., Bush, Elk, and Pocomoke) contained the fewest total taxa. The total number of taxa for those basins that traverse the Fall Line (i.e., Gunpowder, Patapsco, Patuxent, and Potomac Washington Metro) had, on average, 15% more taxa than basins not traversing the Fall Line.

Most of the genera sampled during the MBSS were rare. Two hundred eighty-seven (287) genera (83%) occurred at less than 10% of all sites and 161 genera (47%) occurred at less than 1% of all sites. In contrast, only 14 genera (3%) occurred at more than 25% of all sites. The three most common genera were all dipterans—*Parametriocnemus* sp. and *Cricotopus/Orthocladius* sp. (both Diptera: Chironomidae), and *Prosimulium* sp. (Diptera: Simuliidae)—each occurring at more than 50% of all sites. Other common genera and their respective percent occurrences were *Ephemerella* sp. (Ephemeroptera: Ephemerellidae) (46%), *Stenonema* sp. (Ephemeroptera: Heptageniidae) (40%), and *Hydropsyche* sp. (Trichoptera: Hydropsychidae) (42%).

Mean taxa richness per site statewide was 17.3 (Table 4-13; Figure 4-20). Mean taxa richness was highest in the 1995 sampling of the Youghiogheny basin (23.6) and lowest in the Bush basin (10.4). Taxa richness varied little with stream order; the mean richness was 17.0 for all first-order streams, 18.1 for second-order streams, and 17.9 for third-order streams. However, mean taxa richness did increase consistently with watershed size (Figure 4-21). Stream sites with watersheds > 3,000 acres contained, on average, 13% more taxa than sites with watersheds < 300 acres.

4.3 AMPHIBIANS AND REPTILES

Forty-five species of amphibians and reptiles were observed statewide (Appendix C, Table C-4). Because amphibians and reptiles were collected as part of the Survey's stream-based design, they are a sample of those species that reside in streams and their riparian zones. These amphibian and reptiles are a subset of the larger set of herpetofauna of the State that includes many primarily terrestrial species. The 45 species collected by the Survey represent 52% of the amphibians and reptiles known to exist in the State (Harris 1975); a list of species not reported by the Survey is included in Appendix C, Table C-5.

The Lower Potomac basin had the highest amphibian and reptile species richness per stream mile of riparian area (mean of 4.0 species observed per site). Mean species richness in other basins ranged from 1.4 to 3.3 (Table 4-14). As expected from their aquatic habits, amphibian species (frogs, toads, and salamanders) were the most commonly observed groups, with frogs and toads present at an estimated 44% of stream miles and salamanders present at an estimated 40% of stream miles. Reptiles were less frequently observed: turtles were present at an estimated 7% of stream miles, snakes at 5%, and lizards at 0.4%. No strong pattern of total amphibian and reptile species richness was observed among stream orders. Salamanders, however, were significantly more common in smaller streams, occurring in 41% of first-order and 39% of second-order stream miles, but only 27% of third-order stream miles (Figure 4-22). The species richness of salamanders in low-order streams may make them effective indicators of biological integrity in small streams with few or no fish.

Statewide, distinct geographic patterns were evident in both amphibian groups. The presence of each reptile group was lower and widely distributed across the State. More details on the geographic distributions of amphibian and reptile species is provided in Chapter 12. The number of stream miles with salamanders present declines from west to east in Maryland (Figure 4-23). Indeed, no salamanders were recorded in two Eastern Shore basins: the Nanticoke/-Wicomico and Pocomoke. In contrast, frogs were present in a greater percentage of stream miles on the Eastern Shore of Maryland than in other regions of the State (Figure 4-24). These distributions likely reflect the affinity of salamanders for small streams that are abundant in western Maryland and the affinity of frogs for streams associated with wetlands in eastern Maryland.

4.4 MUSSELS

Throughout the United States, native freshwater mussels are imperiled by human impacts. The Nature Conservancy reports that two-thirds of the nation's freshwater mussels are at risk of extinction and that almost 10% may already have gone extinct (TNC 1998). Currently, there are 16 unionid bivalve species reported in Maryland (pers. comm. J. McCann, Maryland Department of Natural Resources, 1998). Of these, 14 are listed as State rare or endangered species and are actively tracked by DNR's Wildlife and Heritage Division.

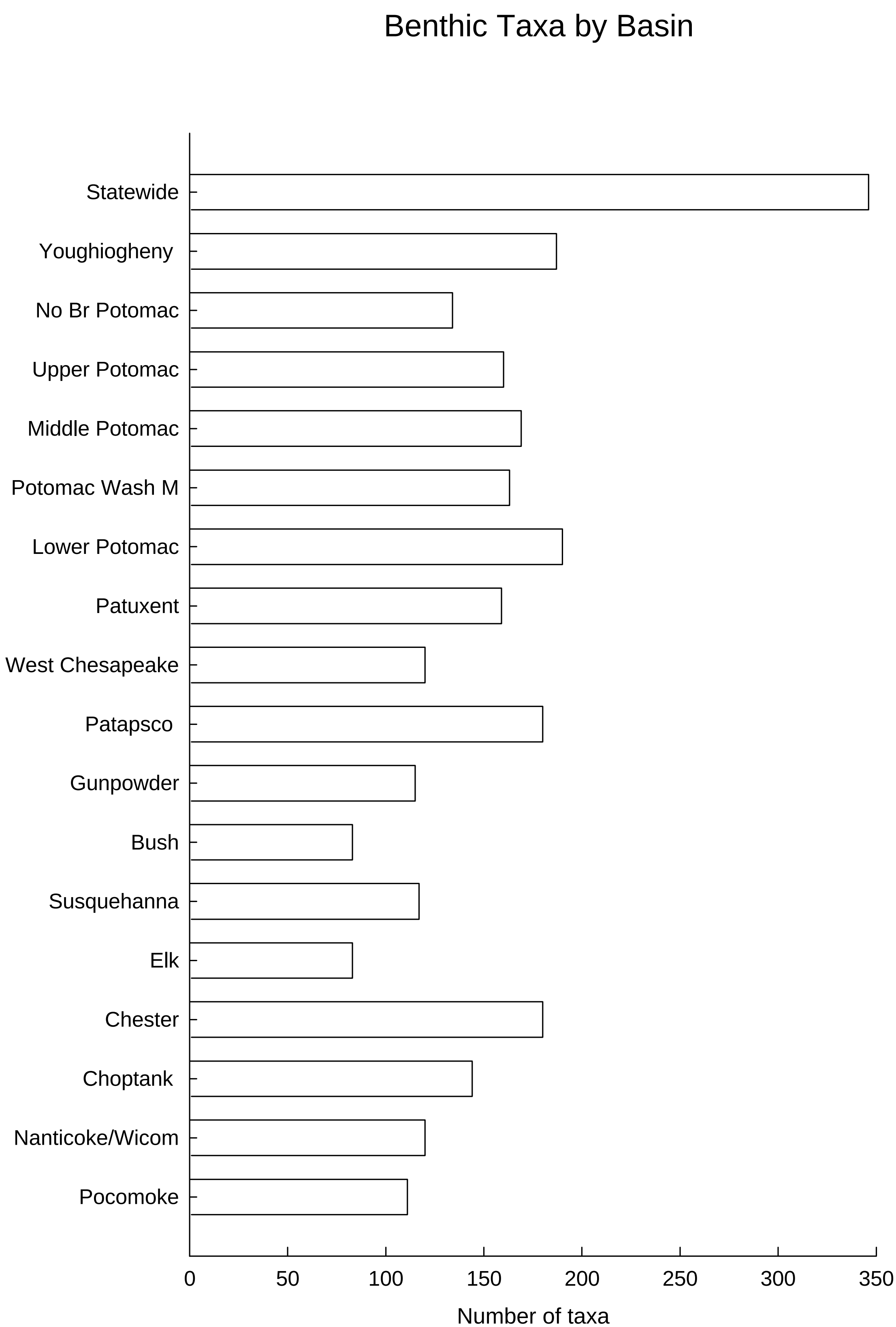


Figure 4-19. Number of benthic taxa, statewide and by basin for the 1995-1997 MBSS

Table 4-13. Benthic taxa richness, by basin and stream order, estimated as mean number of taxa per site, for the 1995-1997 MBSS		
	Mean number of benthic taxa per site	**Standard Error**
Basin		
Youghiogheny 1995	23.6	2.1
Youghiogheny 1997	19.9	2.4
North Branch Potomac	17.4	1.5
Upper Potomac	17.5	1.1
Middle Potomac	14.6	1.2
Potomac Washington Metro	18.7	1.5
Lower Potomac	19.0	2.2
Patuxent	20.0	1.2
West Chesapeake	13.2	2.4
Patapsco 1995	18.3	1.8
Patapsco 1996	12.9	1.3
Gunpowder	18.4	1.6
Bush	10.4	1.9
Susquehanna	19.7	2.0
Elk	16.1	3.4
Chester	18.4	2.7
Choptank 1996	14.2	1.9
Choptank 1997	15.4	2.2
Nanticoke/Wicomico	18.0	4.1
Pocomoke	13.5	1.9
Stream Order		
1	17.0	1.9
2	18.1	2.0
3	17.9	1.2
Statewide	17.3	1.8

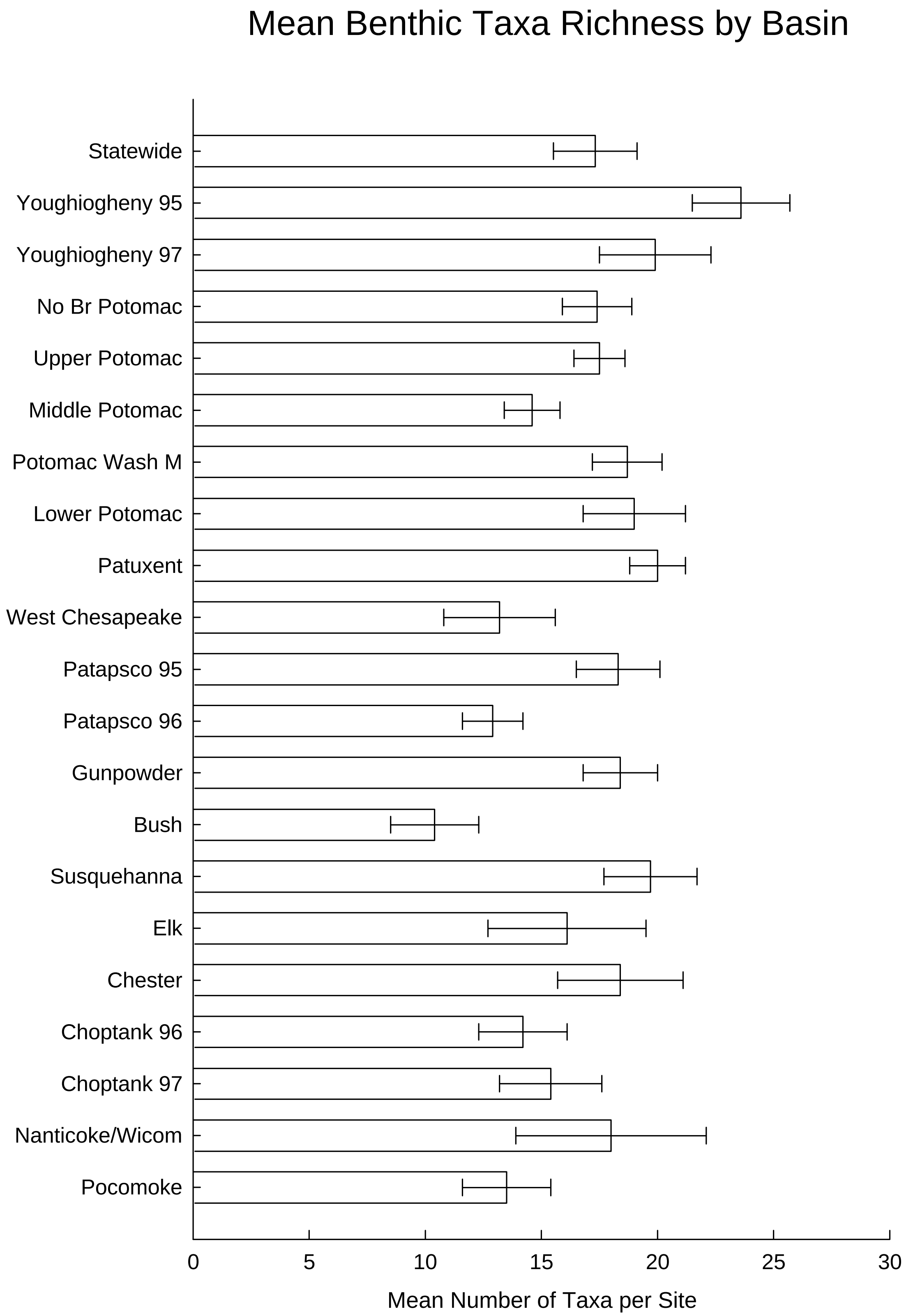


Figure 4-20. Mean benthic taxa richness (mean number of benthic taxa per site), statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

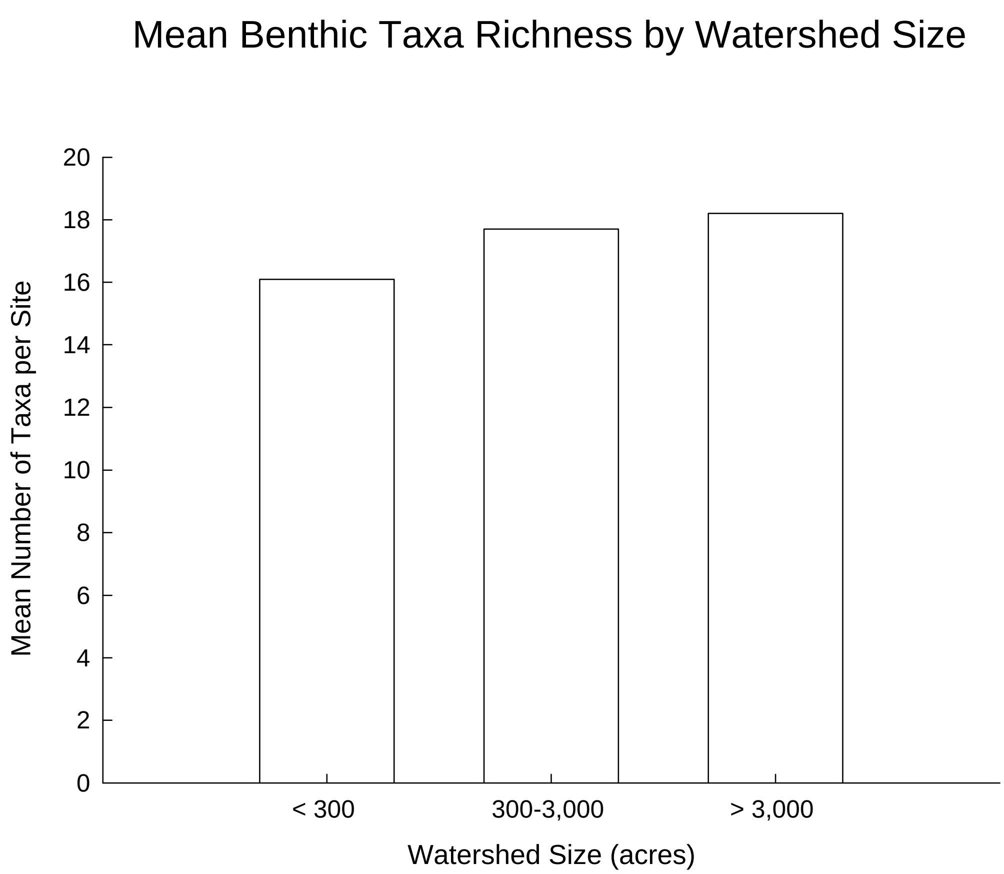


Figure 4-21. Mean benthic taxa richness (mean number of benthic taxa per site), statewide, by watershed size (acres)

Table 4-14. Amphibian and reptile species richness, by basin and stream order, estimated as mean number of species per segment, for the 1995-1997 MBSS

	Mean number of amphibians and reptile species per site	Standard Error
Basin		
Youghiogheny 1995	2.5	0.6
Youghiogheny 1997	1.4	0.3
North Branch Potomac	3.0	0.4
Upper Potomac	2.2	0.3
Middle Potomac	1.8	0.2
Potomac Washington Metro	2.4	0.3
Lower Potomac	4.0	0.5
Patuxent	3.2	0.3
West Chesapeake	2.0	0.4
Patapsco 1995	2.0	0.2
Patapsco 1996	2.1	0.3
Gunpowder	2.2	0.3
Bush	1.7	0.4
Susquehanna	3.2	0.4
Elk	2.1	0.7
Chester	2.6	0.5
Choptank 1996	2.8	0.7
Choptank 1997	3.3	0.8
Nanticoke/Wicomico	1.9	0.5
Pocomoke	2.2	0.6
Stream Order		
1	2.6	0.3
2	2.3	0.2
3	2.1	0.2
Statewide	2.5	0.3

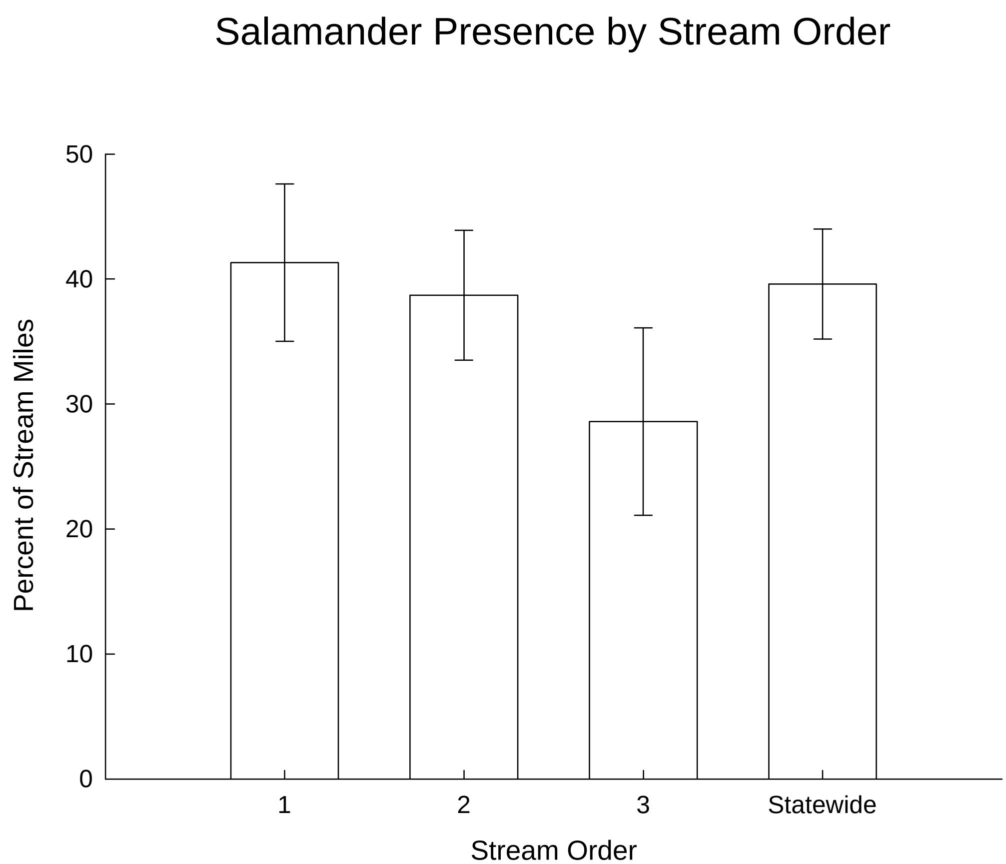


Figure 4-22. Percentage of stream miles with salamanders present, by stream order for the 1995-1997 MBSS. Error bars signify ±1 standard error.

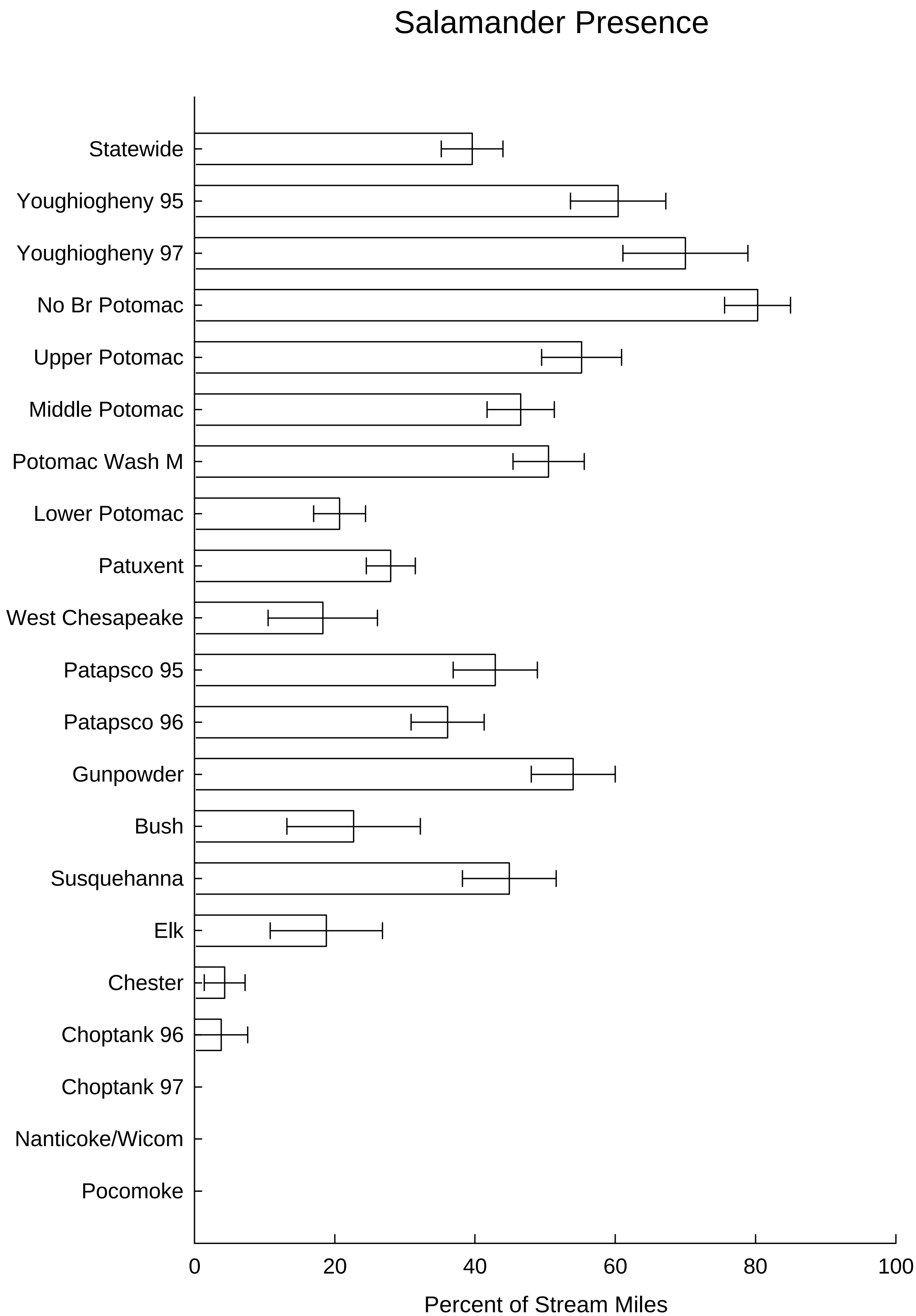


Figure 4-23. Percentage of stream miles with salamanders, statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

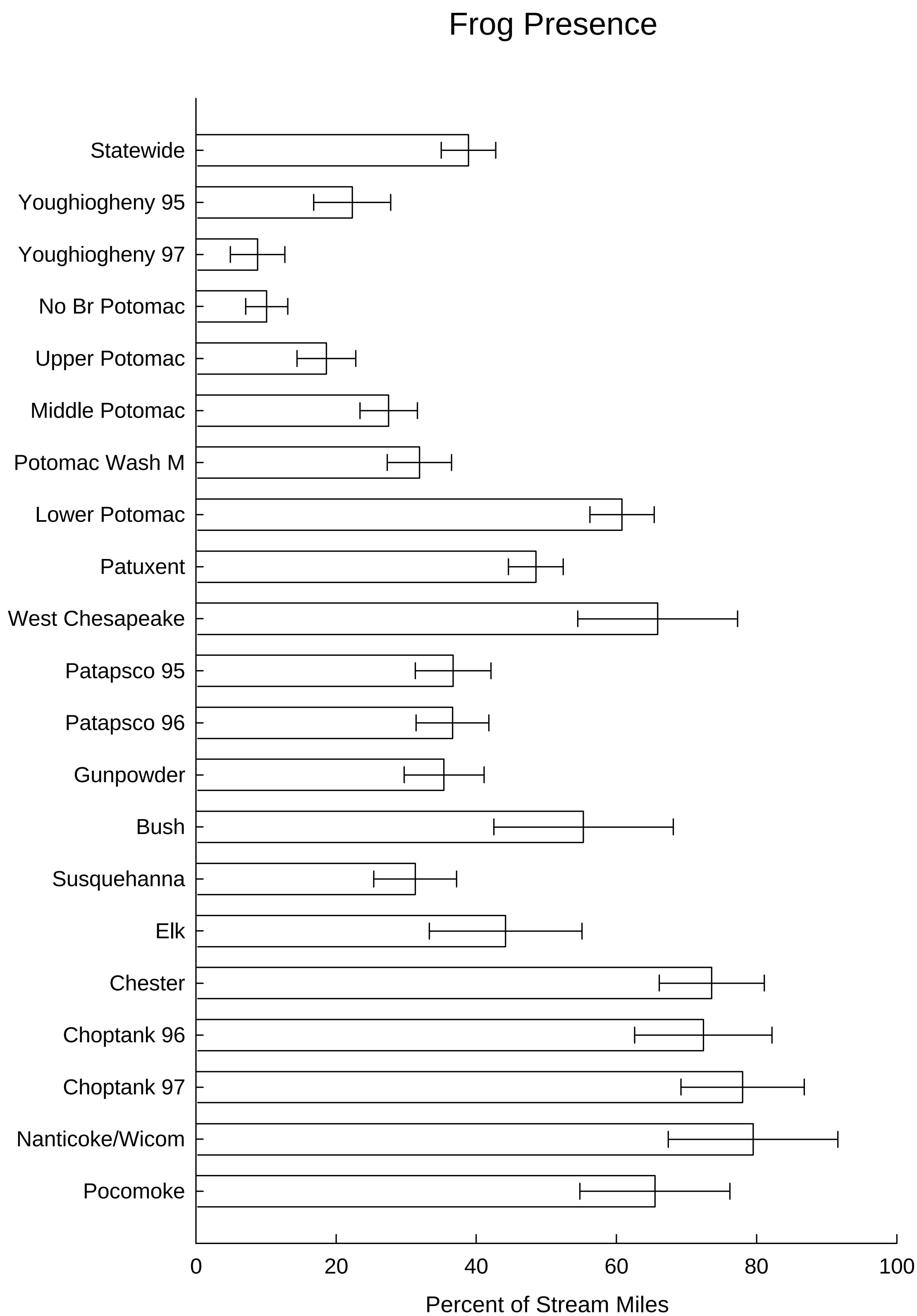


Figure 4-24. Percentage of stream miles with frogs, statewide and for basins sampled in the 1995-1997 MBSS. Error bars signify ±1 standard error.

Eight species of freshwater bivalves were collected in Maryland from 1995-1997 (Appendix C, Table C-6), including seven native unionid species and the introduced Asiatic clam. Five state rare unionid species were observed during the Survey. For further details on rare and introduced species, see Chapter 12.

Sixteen of the basins across the state contained one or more of the species found. The Chester basin had the highest species richness with six native freshwater bivalves collected, whereas no bivalves were collected in the North Branch Potomac basin (Figure 4-25). Overall, freshwater unionid mussels were found at 18% of the 905 core MBSS sites sampled statewide. Strayer (1983) and Watters (1993) have indicated that mussel species diversity in streams often increases as stream order increases. This is consistent with MBSS results for 1995-1997 where unionid mussels were present in 2% of the first-order sites sampled, 9% of the second-order sites, and 19% of the third-order sites.

The two most common freshwater bivalves were the eastern elliptio (occurring at 7.9% of sites) and the introduced Asiatic clam (7.7%). The Asiatic clam, although first introduced to the region in the early 1930's, is now widespread in Maryland, occurring in 13 of the basins sampled (Figure 4-26). Other species of bivalves occurred at less than 1% of all sites sampled. The squawfoot and yellow lance, both listed as rare in Maryland, occurred at only one of 905 sites sampled. Currently, there is concern about the status of the squawfoot due to its rarity in Maryland, as well as the yellow lance which is difficult to identify.

4.5 AQUATIC VEGETATION

Aquatic vegetation communities are an important component of small stream ecosystems, often becoming the primary transducer of energy from sunlight to organic matter in unshaded environments (Lock 1981). Plants also create habitats for invertebrates (Biggs 1996, Newman et al. 1996), slow water velocities (Sand-Jensen and Mebus 1996), trap detritus (Dudley et al. 1986), and provide food and cover for fish (Sevino and Stein 1982). When abundant, aquatic vegetation controls flow conditions, carbon and mineral flux, and the abundance and species composition of invertebrates and fishes (Sand-Jensen and Mebus 1996). Recognizing the importance of aquatic vegetation communities to streams, the Survey recorded the presence and species composition of aquatic vegetation at all sample sites.

During the 1995-1997 MBSS, 24 distinct taxa of aquatic vegetation were identified (Table 4-15; Appendix C, Table C-7). Burreed (*Sparganium* sp.), an emergent, obligate wetland species, was the most abundant species, occurring at 11.3% (102) of the 905 sites sampled. Larger water-starwart (*Callitriche heterophylle*), a submerged aquatic species, occurred at 8.7% of sites, while pondweed (three *Potamogeton* species submerged aquatic) and water purslane (*Ludwigia palustris* emergent) were found at 5.5% of sites. Because of the synoptic nature of the Survey (plant communities were sampled only one time), many plant taxa could not be identified to species because flowering parts and other key identifiers were not apparent. As a result, we were not able to determine whether rare species were collected during the Survey.

Aquatic vegetation in streams typically occurs in dense, monospecific patches that vary according to flow regime and shading (Butcher 1933). Shading is particularly important, and streams with substantial shading may not receive enough light to allow aquatic vegetation growth regardless of the water or substrate quality (Simonson et al. 1994). The Survey revealed that streams with 20% shading or less had an average of 1.6 species per site, whereas streams with greater than 80% shading averaged less than 0.25 species per site (Figure 4-27). As 95% of Maryland was once forested, it is likely that, with the exception of beaver impoundments, more aquatic vegetation exists in Maryland's non-tidal streams today than prior to European settlement.

As expected, aquatic vegetation was far more widespread in Coastal Plain basins (Figure 4-28). Within the Coastal Plain, the Choptank and Pocomoke basins had the highest mean number of species per site (2.4). The difference in abundance and diversity between regions is likely a result of lower water velocities in Coastal Plain streams, but the extensive network of ditched streams with little or no canopy probably played a role as well. Taxa richness was higher in large streams than small (and theoretically more shaded) streams in the Coastal Plain (Figure 4-29). In contrast, there was no apparent relationship between taxa richness and stream size in the non-Coastal Plain, possibly because their requirements for soft substrates and slow stream flows are not met in higher gradient streams.

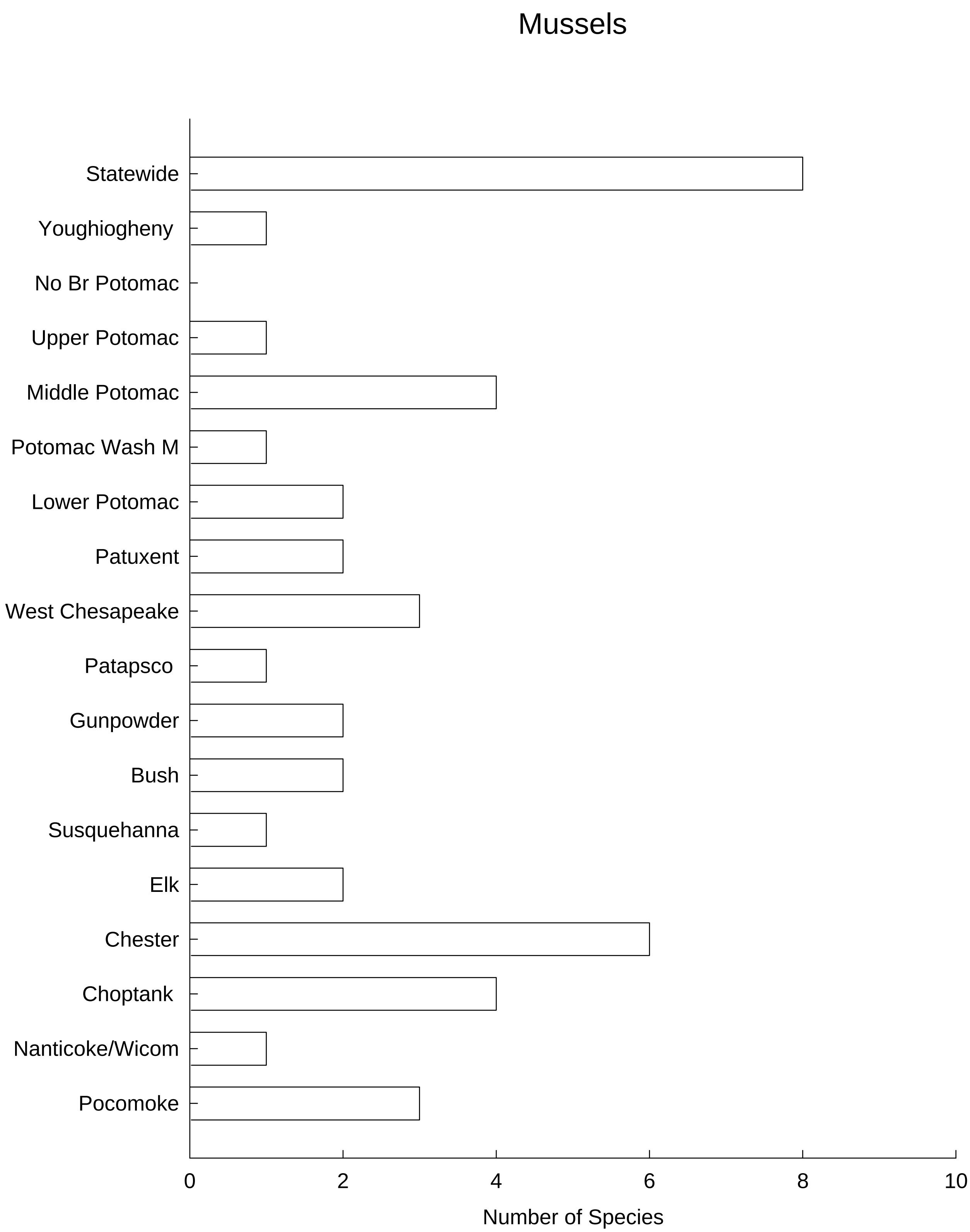


Figure 4-25. Number of mussel species, statewide and for basins sampled in the 1995-1997 MBSS

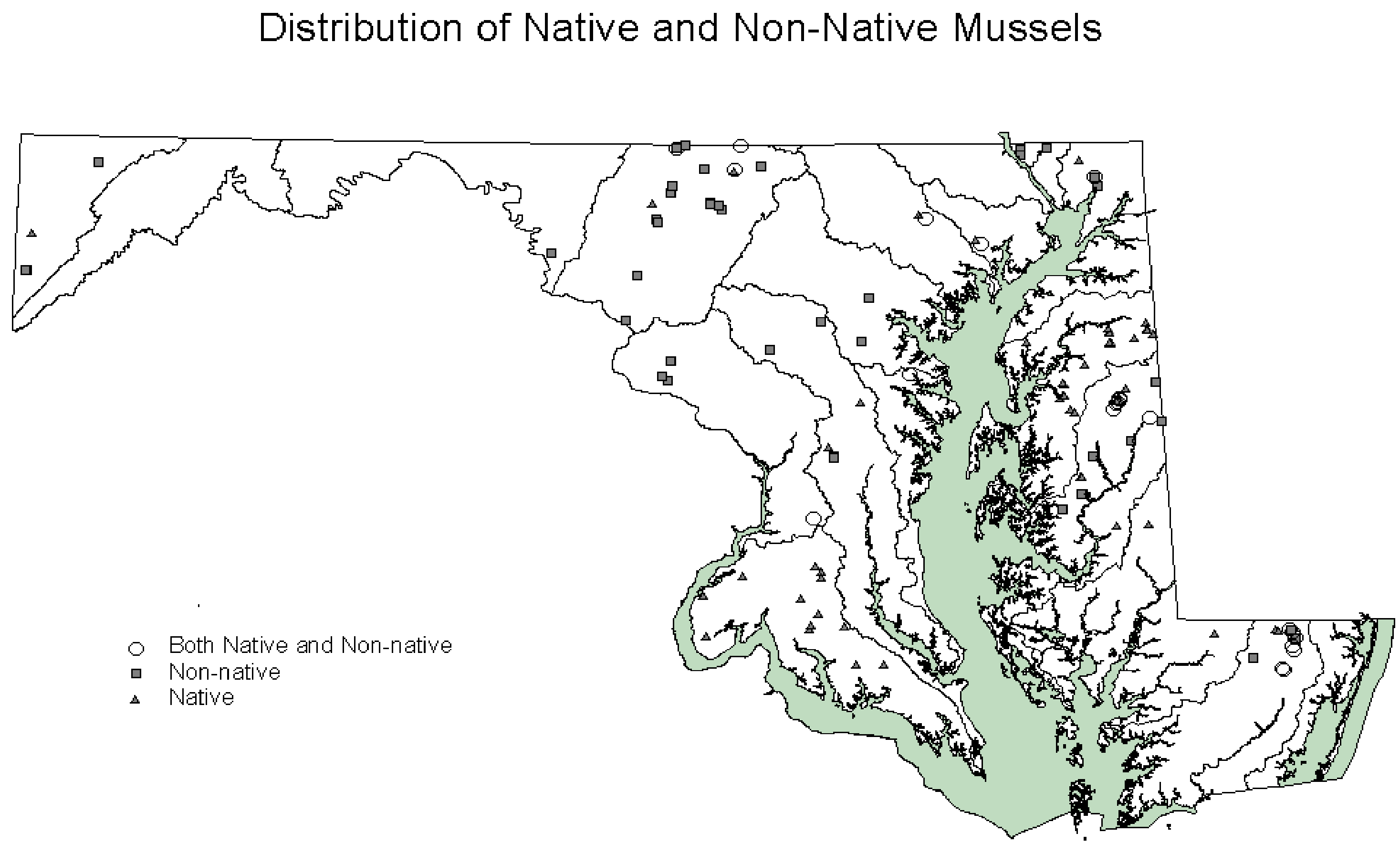


Figure 4-26. Distribution of native and non-native mussels species recorded in the 1995-1997 MBSS. Native refers to unionid mussels native to Maryland. Non-native indicates the presence of Asiatic clam (*Corbicula fluminea*).

Table 4-15. Aquatic plant species present by basin for the 1995-1997 MBSS

	Youghiogheny	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washingtion Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank	Nanticoke/Wicomico	Pocomoke
Submerged																	
Larger water-starwort									X					X		X	
Coontail														X	X		
Elodea	X			X					X	X	X	X					
Hydrilla															X		
Eurasian watermilfoil											X						
Naiad						X					X				X		
Riverweed													X		X		
Curly pondweed					X		X			X	X	X	X				
Floating pondweed	X				X		X	X	X					X	X	X	X
Small pondweed				X			X					X					
Water celery								X					X		X		X
Horned pondweed					X												
Emergent																	
Common water plantain						X	X		X								
Water pennywort													X	X	X		
Water purslane								X						X	X		X
Watercress				X			X		X			X					
Arrow arum				X	X	X	X										X
Pickerel weed						X											
Arrow head				X													
Lizard's tail								X					X		X		X
Burreed	X			X	X	X	X	X	X	X	X		X	X	X	X	X
Cattail			X				X								X		
Floating																	
Duckweed			X					X		X					X		X
Yellow water lily						X		X									X

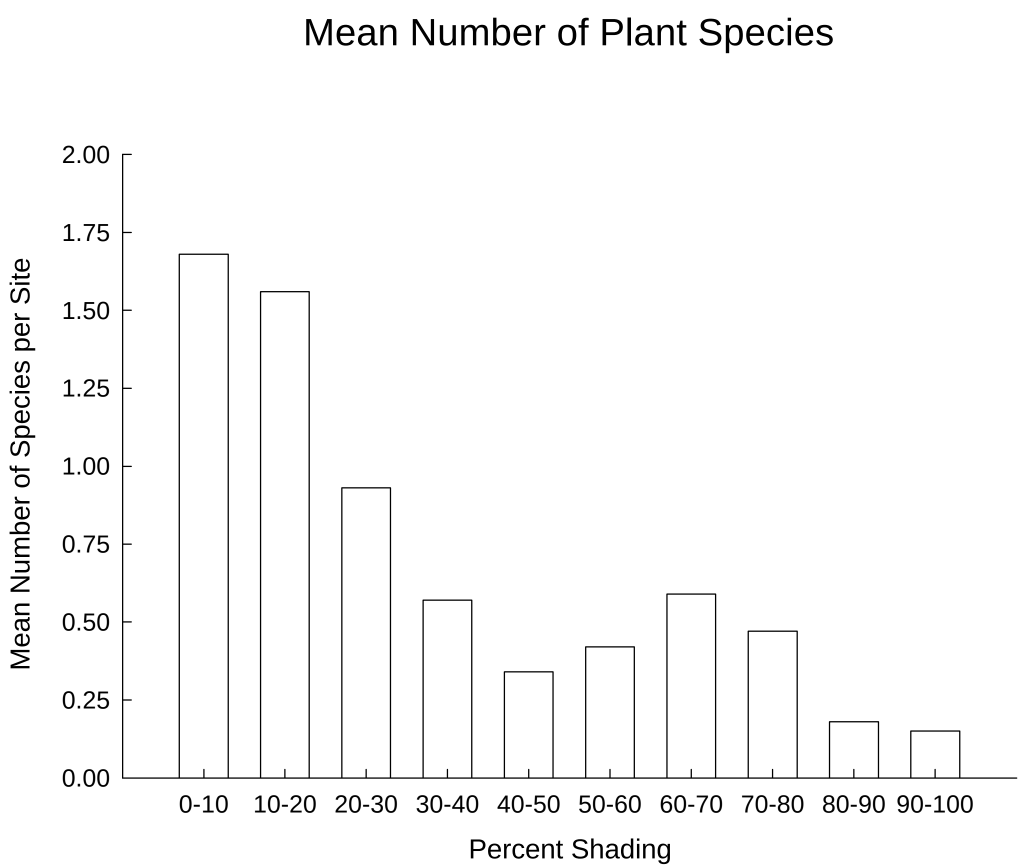


Figure 4-27. Mean number of aquatic plant species per site based on the percent shading received at each site for the 1995-1997 MBSS

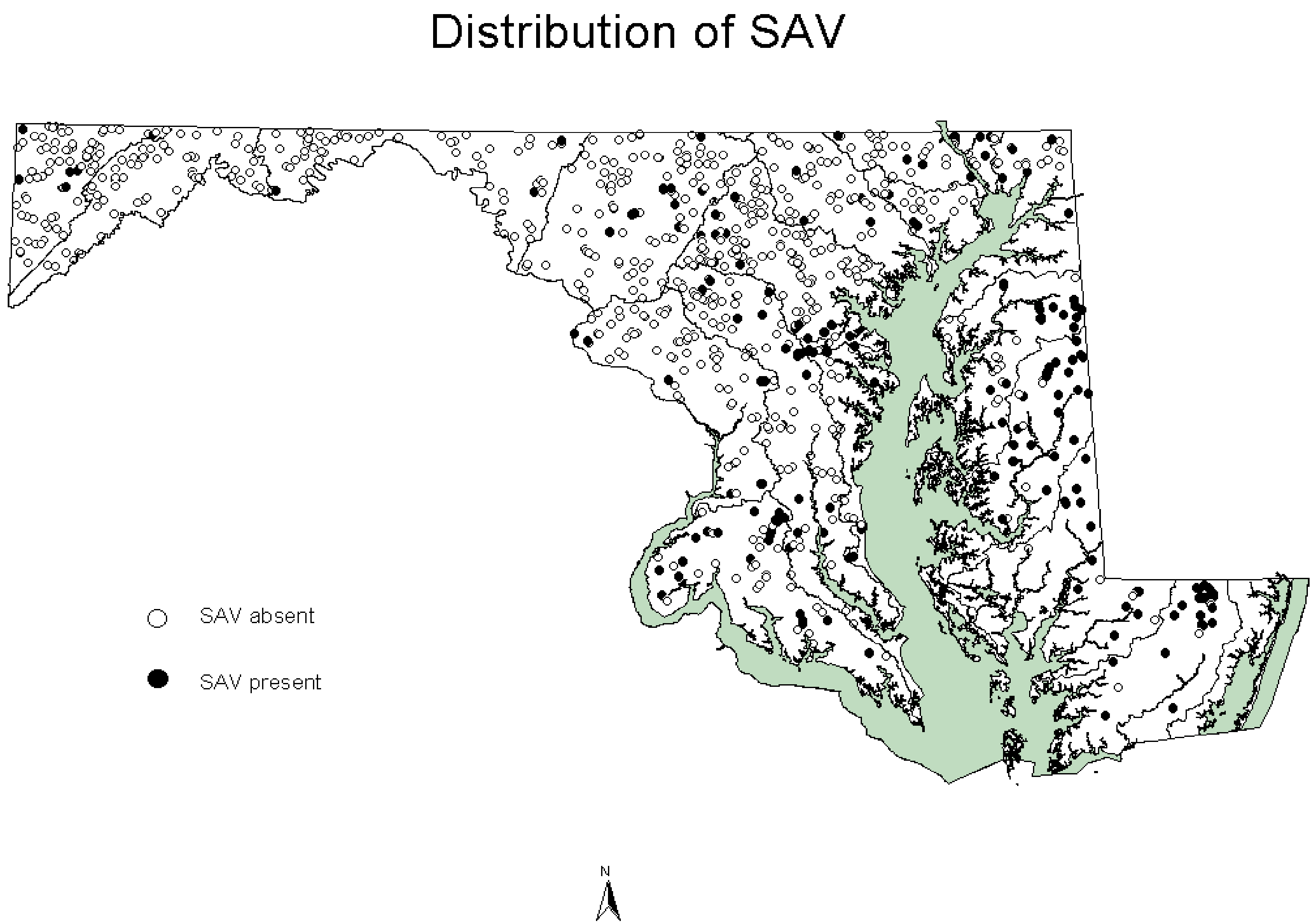


Figure 4-28. Distribution of submerged aquatic vegetation recorded the 1995-1997 MBSS

Figure 4-29. Mean number of aquatic plant species per site, by stream order, for Coastal Plain and non-Coastal Plain sites in the 1995-1997 MBSS

5 ASSESSMENT OF BIOLOGICAL CONDITION

This section presents the assessment results of the 3-year sampling effort, describing the biological condition of streams in the basins sampled by the Maryland Biological Stream Survey (MBSS, or the Survey). Identification of degraded and undegraded streams is based on the assignment of ratings for the fish Index of Biotic Integrity (IBI) and the benthic IBI. Streams are also evaluated using the Hilsenhoff Biotic Index for benthic macroinvertebrates. Finally, the section compares the results of the fish IBI with the benthic IBI and the Hilsenhoff Biotic Index.

5.1 INTRODUCTION TO THE INDEX OF BIOTIC INTEGRITY

The Index of Biotic Integrity is a stream assessment tool that evaluates biological integrity based on characteristics of the fish and benthic assemblage at a site. Biological integrity is defined as the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region (Karr and Dudley 1981 as cited in Karr 1991).

To develop an IBI, reference sites are selected to represent regional natural habitats, also referred to as "minimally impacted" conditions. We recognize that virtually no streams in Maryland are entirely undisturbed by human activities. Atmospheric deposition of contaminants alone reaches all parts of the State, few streams have natural temperature regimes, and more than 1,000 man-made barriers to fish migration have been documented in Maryland. Therefore, our reference conditions should not be viewed as completely natural or pristine. They are, however, a representative sample of the best streams that currently exist in the State. Whether these conditions are the best attainable depends on future restoration activities and the goals of DNR and the public.

By definition, reference conditions represent minimally impacted conditions or those approximating "natural habitats." While some have suggested that reference conditions can be developed for particular situations where human impact is evident, such as urban streams, we have not taken this approach. Instead, reference sites were used to establish appropriate expectations, based on minimally impacted sites within a geographic region, and urban streams are rated on the same scale as other sites in the region. Although some urban streams may not be able to recover to a level comparable to the best natural habitats, appropriate management goals could be set using some intermediate IBI value as a desirable goal. This strategy could be used to maintain or restore a heavily impacted stream to a level of biological condition that is practical and attainable, given its history of degradation and current level of watershed development.

5.2 INTERPRETING THE INDEX OF BIOTIC INTEGRITY

Sites were evaluated using both the fish and benthic IBIs developed for the MBSS (for detailed methods, see Roth et al. 1997 and Stribling et al. 1998). IBI scores for the MBSS are determined by comparing the fish or benthic assemblages at each site to those found at minimally impacted reference sites. Three separate formulations were employed for the fish IBI, one for each of three distinct geographic areas: Coastal Plain, Eastern Piedmont, and Highland (Figure 5-1). The two formulations used for the benthic IBI cover the Coastal Plain and non-Coastal Plain regions. Individual metrics for the IBI are scored 1, 3, or 5, based on comparison with the distribution of metric values at reference sites (see Tables 5-1 to 5-4). For either the individual metrics or total IBI, a score of 3 or greater is considered comparable to reference site conditions, while scores falling below this threshold differ significantly from the reference conditions, as shown in Figure 5-2. Scores for the MBSS IBIs are calculated as the mean of the individual metric scores and therefore range from 1 to 5. Some other programs have used a similar approach (e.g., Weisberg et al. 1997), while others have instead computed the IBI as the total of individual metric scores. For example, Karr et al. (1986) calculated IBI as the sum of 12 metric scores, with totals ranging from 12 to 60 points.

Site-specific IBI results were used to estimate the extent of non-tidal streams in good, fair, poor, and very poor condition with respect to the biotic integrity of the fish or benthic community. Table 5-5 contains detailed descriptions for each of the IBI categories developed for the MBSS. The IBI score of 3 represents the threshold of reference condition and thus was used to designate sites known to be degraded (i.e., poor or very poor). The highest scores were designated as good recognizing that reference sites may not represent the highest attainable condition. The assignment of scores to narrative categories is a useful method for translating scores into a form that is easily

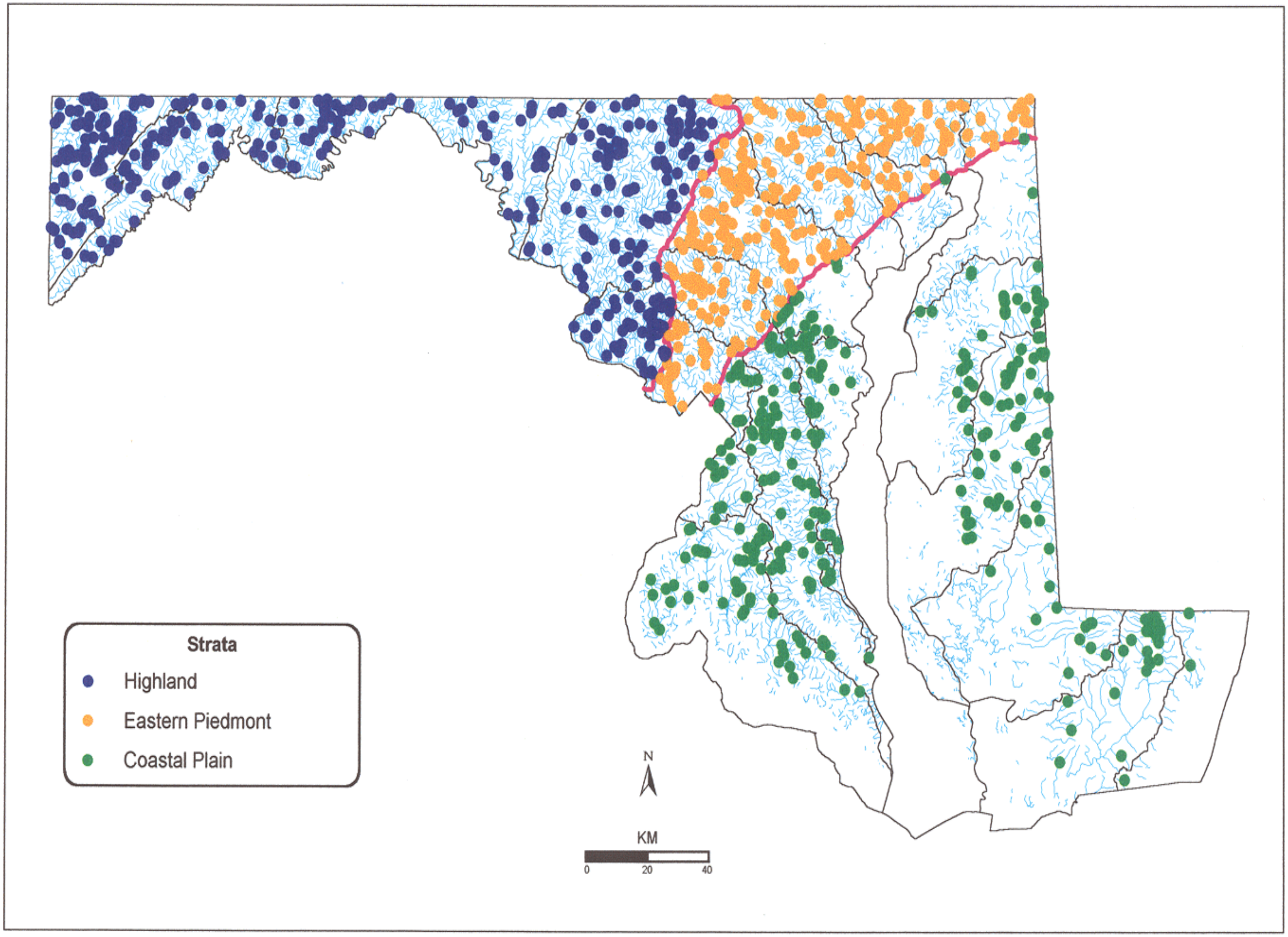


Figure 5-1. The three geographic regions used for the derivation of the fish Index of Biotic Integrity: Coastal, Piedmont, and Highland.

Table 5-1. Metrics and scoring criteria for the recommended final fish IBI. Some metrics[(a)] were adjusted for watershed area, based on linear relationships between the metric and log(watershed area)[(b)] in acres

	Scoring criteria 5	3	1
Coastal Plain			
Number of native species[(a)]	Criteria vary with stream size (see below)		
Number of benthic fish species[(a)]	Criteria vary with stream size (see below)		
Number of intolerant species[(a)]	Criteria vary with stream size (see below)		
Percent tolerant fish	≤ 50	$50 < x \leq 93$	> 93
Percent abundance of dominant species	≤ 33	$33 < x \leq 78$	> 78
Percent generalists, omnivores, and invertivores	≤ 92	$92 < x < 100$	100
Number of individuals per square meter	≥ 0.79	$0.42 \leq x < 0.79$	< 0.42
Biomass (g) per square meter	≥ 9.9	$3.6 \leq x < 9.9$	< 3.6
Eastern Piedmont			
Number of native species[(a)]	Criteria vary with stream size (see below)		
Number of benthic fish species[(a)]	Criteria vary with stream size (see below)		
Number of intolerant species[(a)]	Criteria vary with stream size (see below)		
Percent tolerant fish	≤ 41	$41 < x \leq 65$	> 65
Percent abundance of dominant species	≤ 30	$30 < x \leq 52$	> 52
Percent generalists, omnivores, and invertivores	≤ 86	$86 < x \leq 99.7$	> 99.7
Number of individuals per square meter	≥ 0.81	$0.35 \leq x < 0.81$	< 0.35
Biomass per square meter	≥ 8.0	$3.7 \leq x < 8.0$	< 3.7
Percent lithophilic spawners	≥ 62	$22 \leq x < 62$	< 22
Highland			
Number of benthic fish species[(a)]	Criteria vary with stream size (see below)		
Number of intolerant species[(a)]	Criteria vary with stream size (see below)		
Percent tolerant fish	≤ 28	$28 < x \leq 71$	> 71
Percent abundance of dominant species	≤ 49	$49 < x \leq 91$	> 91
Percent generalists, omnivores, and invertivores	≤ 49	$49 < x \leq 92$	> 92
Percent insectivores	≥ 48	$8 \leq x < 48$	< 8
Percent lithophilic spawners	≥ 70	$42 \leq x < 70$	< 42

Table 5-1. Cont'd

[(a)] Adjusted value = observed value/expected value, where expected value = m * log(watershed area in acres) + b.

	Scoring criteria		
	5	**3**	**1**
Coastal Plain			
Number of native species - Adjusted value	≥ 1.06	0.53 ≤ x <1.06	< 0.53
Number of benthic fish species - Adjusted value	≥ 1.06	0 < x < 1.06	0
Number of intolerant species Adjusted value	≥ 0.34	0 < x < 0.34	0
Eastern Piedmont			
Number of native species - Adjusted value	≥ 1.02	0.56 ≤ x < 1.02	< 0.56
Number of benthic fish species - Adjusted value	≥ 0.99	0.50 ≤ x < 0.99	< 0.50
Number of intolerant species Adjusted value	≥ 0.59	0.18 ≤ x < 0.59	< 0.18
Highland			
Number of benthic fish species - Adjusted value	≥ 1.03	0.33 ≤ x < 1.03	< 0.33
Number of intolerant species Adjusted value	≥ 0.73	0.23 ≤ x < 0.73	< 0.23

[(b)] Slope and intercept values for selected metrics, based on linear regression relationships between metric and log(watershed area) in acres

	slope (m)	**intercept(b)**
Coastal Plain		
Number of native species	6.5936	-13.0055
Number of benthic fish species	1.5743	-3.3929
Number of intolerant species	2.1485	-5.286
Eastern Piedmont		
Number of native species	5.5701	-8.1135
Number of benthic fish species	1.3245	-2.6437
Number of intolerant species	4.4052	-8.8991
Highland		
Number of benthic fish species	1.6067	-3.5202
Number of intolerant species	3.0723	-7.3029

Table 5-2. Description of fish IBI metrics

Number of native species (adjusted for watershed area) - Total number of native fish species; adjusted for watershed area (see Table 5-1b). Fishes were classified as native or introduced to Chesapeake Bay or Youghiogheny/Ohio River drainage.

Number of benthic fish species (adjusted for watershed area) - The number of fish species that reside primarily on the stream bottom, adjusted for watershed area (see Table 5-1b). Benthic fishes include all darters (*Etheostoma* spp., *Perca* spp.), sculpins (*Cottus* spp.), madtoms (*Noturus* spp.), and lampreys (*Petromyzon* spp., *Lampetra* spp.).

Number of intolerant species (adjusted for watershed area) - The number of fish species rated as intolerant of anthropogenic stress, adjusted for watershed area. Tolerance ratings (intolerant, tolerant) were based on statewide analysis comparing species occurrences with presence/absence of anthropogenic stressors.

Percentage tolerant fish - Percentage of individuals rated as tolerant to anthropogenic stress.

Percentage abundance of dominant species - Percentage of individuals within the single most abundant (dominant) species at a site.

Percentage generalists, omnivores, and invertivores - Percentage of individuals classified into the trophic groups of generalist, omnivore, or invertivore; these are the most general of all feeding habits. Invertivores eat insects and other invertebrates including crustaceans, mollusks, and worms. Omnivores consume two or more food types (insects, invertebrates other than insects, fish, plankton, algae, vascular plants, and detritus) with the exception of the combination of invertebrates and fishes. Generalists eat both invertebrates and fishes but not other food items.

Percentage insectivores - Percentage of individuals classified into the group insectivore; this is a specialized trophic group, feeding almost exclusively on insects.

Number of individuals per square meter - The number of individuals captured at a site, divided by the surface area fished. Surface area was computed as length of stream fished (usually 75 m) multiplied by average stream width.

Biomass (g) per square meter - Total mass in grams of fish captured at a site, divided by the surface area fished.

Percentage lithophilic spawners - Percentage of individuals reported to use rock substrates for spawning.

Table 5-3. Metrics and scoring criteria for the benthic IBI. From Stribling et al. 1998.

	Scoring Criteria		
	5	**3**	**1**
Coastal Plain			
Total taxa	>24	11<x<24	<11
EPT taxa	6	3<x<6	<3
% Ephemeroptera	>11.4	2.0<x< 11.4	<2.0
% Tanytarsini of Chiron.	>13.0	0.0<x<13.0	<0.0
Beck's Biotic Index	>12	4<x<12	<4
Scraper taxa	>4	1<x< 4	<1
% clingers	>62.1	38.7<x< 62.1	<38.7
Non-Coastal Plain			
Total taxa	>22	16<x<22	<16
EPT taxa	>12	5<x<12	<5
Ephemeroptera taxa	>4	2<x<4	<2
Diptera taxa	>9	6<x< 9	<6
% Ephemeroptera	>20.3	5.7<x<20.3	<5.7
% Tanytarsini	>4.8	0.0<x<4.8	<0.0
Intolerant taxa	>8	3<x<8	<3
% tolerant	<11.8	11.8<x< 48.0	>48.0
% collectors	>31.0	13.5<x<31.0	<13.5

Table 5-4. Description of benthic IBI metrics

Total number of taxa - Total number of benthic taxa in the sample. This measures the overall variety of the macroinvertebrate assemblage.

Number of EPT taxa - Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

Number of Ephemeroptera taxa - Number of mayfly taxa.

Number of Diptera taxa - Number of “true” fly taxa, including midges.

Percentage Ephemeroptera - Percentage of mayfly individuals in the sample.

Percentage Tanytarsini of Chironomidae - Percentage of chironomids in the tribe Tanytarsini.

Percentage Tanytarsini - Percentage of Tantarsini midges to total fauna in the sample.

Number of intolerant taxa - Number of taxa considered to be sensitive to perturbation (Hilsenhoff values 0-3).

Percentage tolerant - Percentage of individuals in taxa considered tolerant of perturbation (tolerance values 7-10).

Beck’s Biotic Index - Weighted sum of intolerant taxa, equal to 2 x (number of Class 1 taxa + number of Class 2 taxa), where Class 1 taxa have tolerance values 0 and 1, and Class 2 taxa have tolerance values from 2 to 4.

Number of scraper taxa - Number of taxa that scrape food from substrate.

Percentage collectors - Percentage of individuals that feed on detrital deposits or loose surface films.

Percentage clingers - Percentage of individuals that are adapted for inhabiting flowing water, such as riffles.

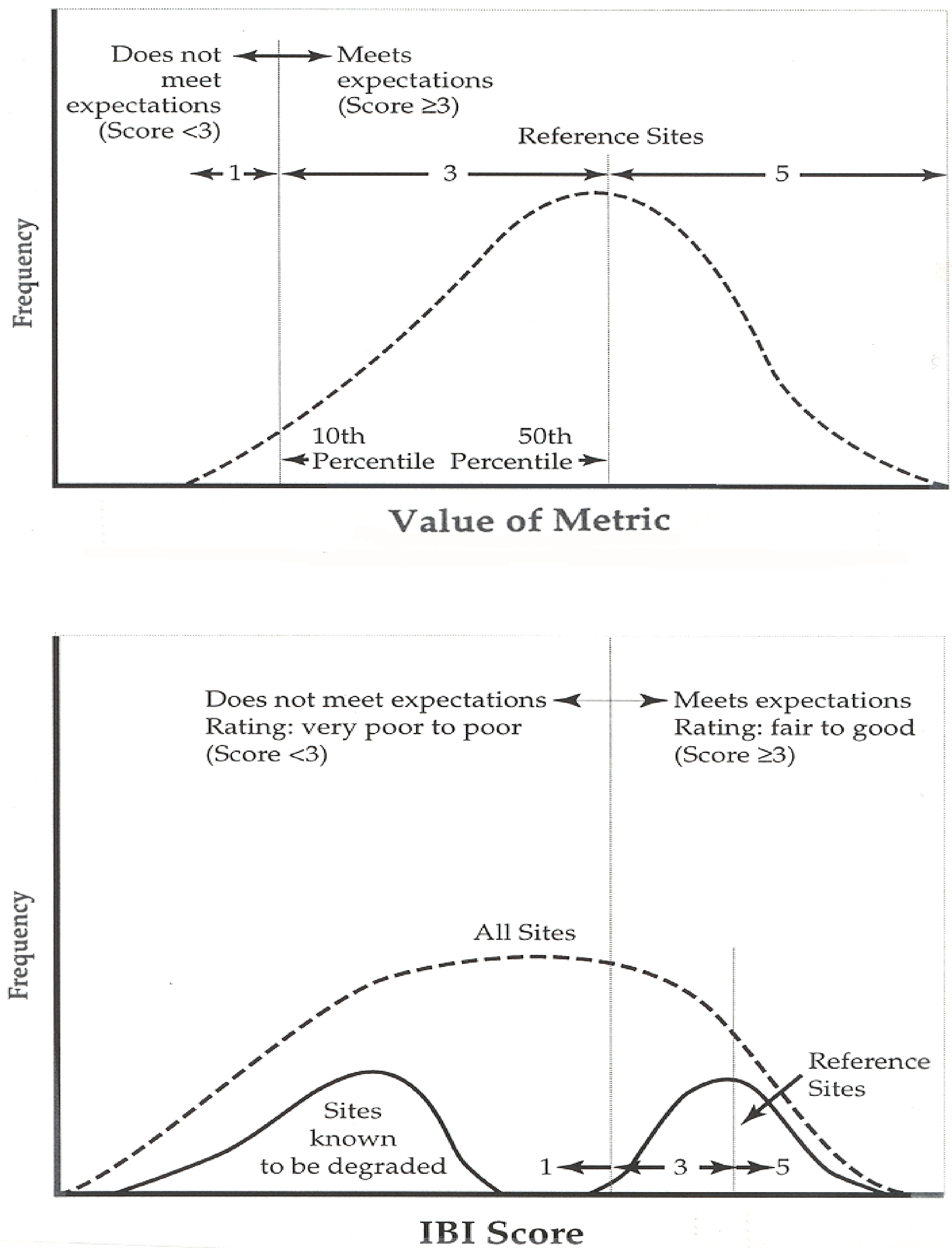


Figure 5-2. Derivation and interpretation of scores for the MBSS fish and benthic Indices of Biotic Integrity (IBI). Scores are based on the distribution of reference sites, as depicted in the top figure. The bottom figure shows reference sites in the context of other sites, including those with known degradation.

Table 5-5. Narrative descriptions of stream biological integrity associated with each of the IBI categories		
Good	IBI score 4.0 - 5.0	Comparable to reference streams considered to be minimally impacted. Fall within the upper 50% of reference site conditions.
Fair	IBI score 3.0 - 3.9	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of these minimally impacted streams. Fall within the lower portion of the range of reference sites (10th to 50th percentile).
Poor	IBI score 2.0 - 2.9	Significant deviation from reference conditions, with many aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating some degradation.
Very Poor	IBI score 1.0 - 1.9	Strong deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating severe degradation.

communicated. Similar approaches have been used in other IBI applications (Karr 1991, Ohio EPA 1987, Ranasinghe et al. 1996).

5.2.1 Special Considerations in Interpreting IBI Scores

Several basins in Maryland contain streams that can be classified as coldwater stream systems. Lyons et al. (1996) and Leonard and Orth (1986) have pointed out the need to modify the IBI for use with coldwater streams, to account for their unique biological characteristics. Generally, high-quality coldwater streams are dominated by salmonid species like brook trout and have lower overall species richness than warmwater systems of the same area. In other parts of North America, fish IBI scores for coldwater and coolwater streams have been tailored to account for their unique biological characteristics. The three regional fish IBIs were used to assess all MBSS sites. However, because the IBI may underrate coldwater streams owing to their naturally low species diversity, the presence of brook trout was used as a secondary indicator in interpreting fish IBI scores. Sites where brook trout were present and fish IBI scores were less than 3 were excluded from analysis and reported as “not rated.” This situation was rare (14 sites) compared to the total number of brook trout sites (70 sites).

Other types of natural variability should be considered in applying the IBI, especially in areas expected to differ in species richness and diversity. Naturally acidic blackwater streams may have lower species richness and be dominated by a few acid-tolerant species. A total of 24 MBSS sites were identified as blackwater streams, defined here as sites with either pH < 5 or ANC < 200 μeq/l and DOC $\geq$ 8 mg/l. Because of the concern for possibly underrating blackwater streams, the nine blackwater streams with fish IBI scores less than 3 were excluded from analysis and were therefore included in the category “not rated.” Maryland DNR is considering developing separate IBIs for more stream types in the future.

Other factors that may affect fish IBI scores should be considered in interpreting scores for individual sites. Small streams with shallow stream channels may naturally support few species. Dams and other barriers to fish migration can block access to formerly inhabited upstream areas. In contrast, proximity of a site to a lake, pond, swamp, or impoundment in a watershed can make a site more accessible to lentic species not typically found in the small streams sampled by the Survey. Nearness to a large river confluence can similarly alter the pool of available species. Finally, high species richness owing to the presence of both Coastal Plain and Piedmont species at sites along the Fall Line may result in artificially high IBI scores in this transitional area.

5.3 BIOLOGICAL INDICATOR RESULTS

5.3.1 Fish IBI Results

Fish IBI scores for sites sampled in the 1995-1997 MBSS spanned the full range of biological conditions, from 5.0 for good streams to 1.0 for very poor streams. Site-specific data were used to estimate the percentage of stream miles in each of the four narrative categories. Estimates were calculated by basin, by stream order, and statewide.

Statewide, the highest percentage of stream miles were in fair condition (26% of stream miles in the study area), based on biological assessments using the fish IBI. An estimated 20% of stream miles were in good condition, 15% of stream miles were in poor condition, and 14% were very poor. A total of 74% of stream miles were rated. The remainder were primarily very small headwater streams (<300 acre watershed) where expectations of fish abundance and diversity are too low for development of an effective indicator. As would be expected, all the watersheds less than 300 acres occurred among first-order streams, most notably in western Maryland. In general, the sample frame included more streams with small watersheds in the western part of the state, where the density of streams is greater. An estimated 63% of first-order stream miles were assigned an IBI score, while 98% of both second- and third-order streams were rated.

Of the 17 basins sampled in the Survey, 14 had fish IBI scores spanning the full range of values from good to very poor. The basins that did not contain the full range of scores included the eastern Maryland basins: Gunpowder, Bush, Elk, Choptank (1996 sampling), Nanticoke/-Wicomico, and Pocomoke basins. These basins each had no sites that were rated as very poor. In addition, the Choptank (1996 sampling) also had no stream miles rated as poor, while the remaining five basins had only a small percentage of sites rated poor (less than 25%). The basin with the highest percentage of stream miles rated as good was the Elk (38%), while the basin with the highest percentage of stream miles rated as very poor was the North Branch Potomac (29%). Figures 5-3, 5-4, and 5-5 and Table 5-6 show a breakdown of fish IBI scores by basin and stream order. A statewide map shows the geographic distribution of IBI scores for each drainage basin (Figure 5-6).

First-order streams had a smaller percentage of stream miles in the good and fair categories, and a greater percentage rated very poor, than did larger streams. This most likely indicates more highly impacted conditions in first-order streams across these basins, or may also reflect a tendency for the IBI to underrate small streams, even though scoring already accounts for some effects of watershed size.

5.3.2 Benthic IBI Results

Benthic macroinvertebrate IBI scores for sites sampled in the 1995-1997 MBSS spanned the full range of biological conditions, from 5.0 for good streams to 1.0 for very poor streams. Site-specific data were used to estimate the percentage of stream miles in each of the four narrative categories. Estimates were calculated by basin, by stream order, statewide.

Statewide, the largest percentage of the stream miles were in fair condition (38% of stream miles) , based on biological assessments using the benthic IBI. An estimated 11% were in good condition, 26% were poor, and 25% were very poor. A total of 99.4% of streams were assigned benthic IBI scores. Because some metrics used to calculate the benthic IBI may not perform well when subsamples contain low numbers of individuals, the land use, water chemistry, physical habitat, and sample processing data from MBSS sites with less than 60 individuals were examined to determine if low numbers were likely a result of sampling error or stream quality. A benthic IBI score was calculated for sites of obviously poor quality. The small percentage of sites for which low numbers of individuals could be attributed to sampling error were not assigned a benthic IBI and were therefore included in the "not rated" category.

Of the 17 basins sampled in the Survey, 13 had benthic IBI scores that spanned the full range of values from good to very poor. The basins that did not contain the full range of scores were the Middle Potomac, Bush, Susquehanna, Elk, and Choptank (1997 sampling) basins. Of these, the Middle Potomac, Bush, Elk and Choptank (1997 sampling) basins each had no sites with IBI scores rated as good, while the Susquehanna had no sites that rated as very poor. In addition, the Pocomoke basin showed only 0.3% of stream miles rated as good. The basin with the greatest percentage of stream miles rated good was the 1995 sampling of the Youghiogheny (44%). The West Chesapeake (70%) and Pocomoke (69%) basins show the greatest percentage of stream miles that rated very poor. Figures 5-7, 5-8, and 5-9 and Table 5-7 show a breakdown of benthic IBI scores by basin and stream order. A statewide map (Figure 5-10) shows the geographic distribution of site IBI scores throughout the sample area.

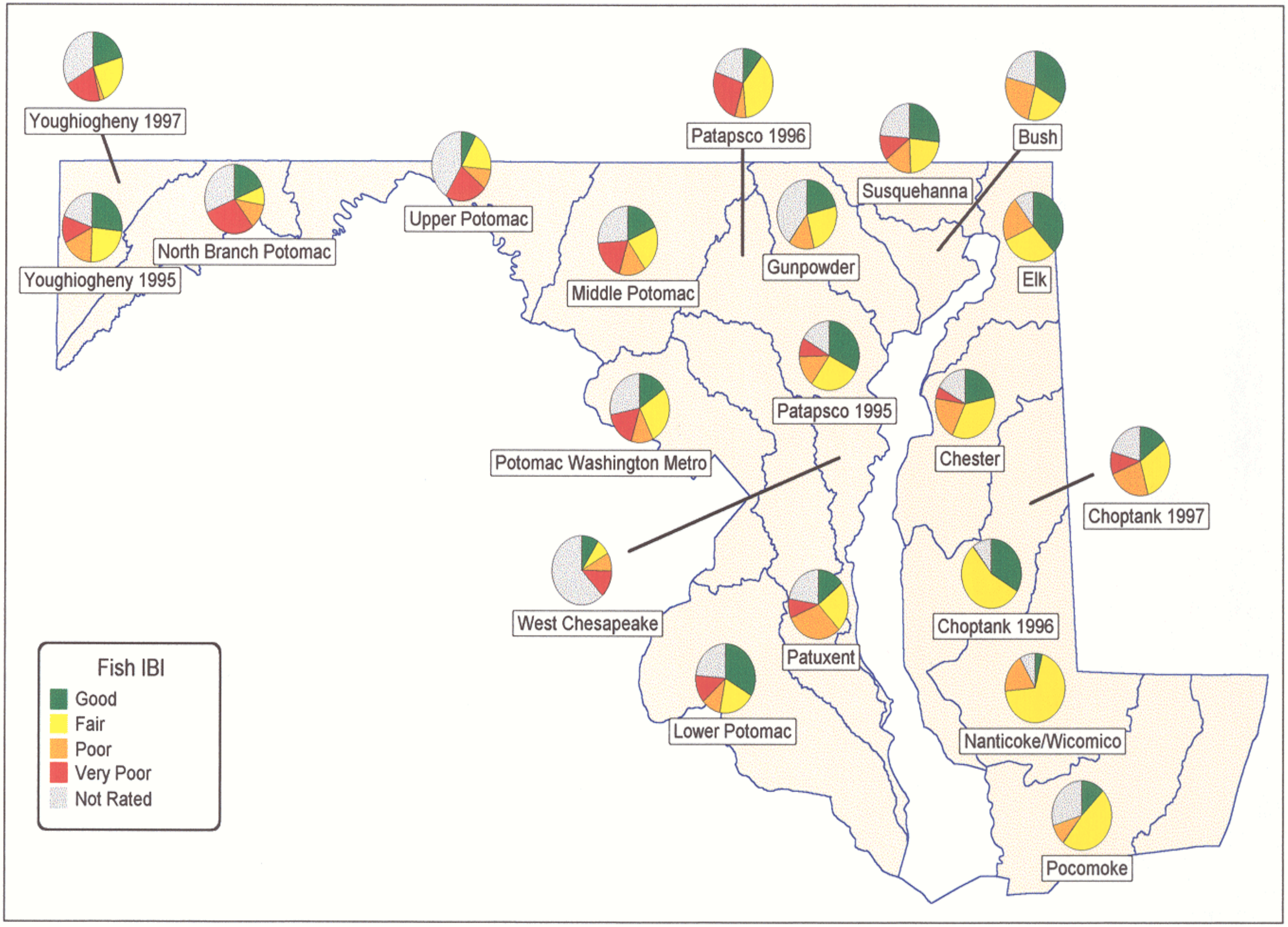


Figure 5-3. Geographic distribution of fish Index of Biotic Integrity scores for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor. No IBI score was assigned to sites with watershed area < 300 acres.

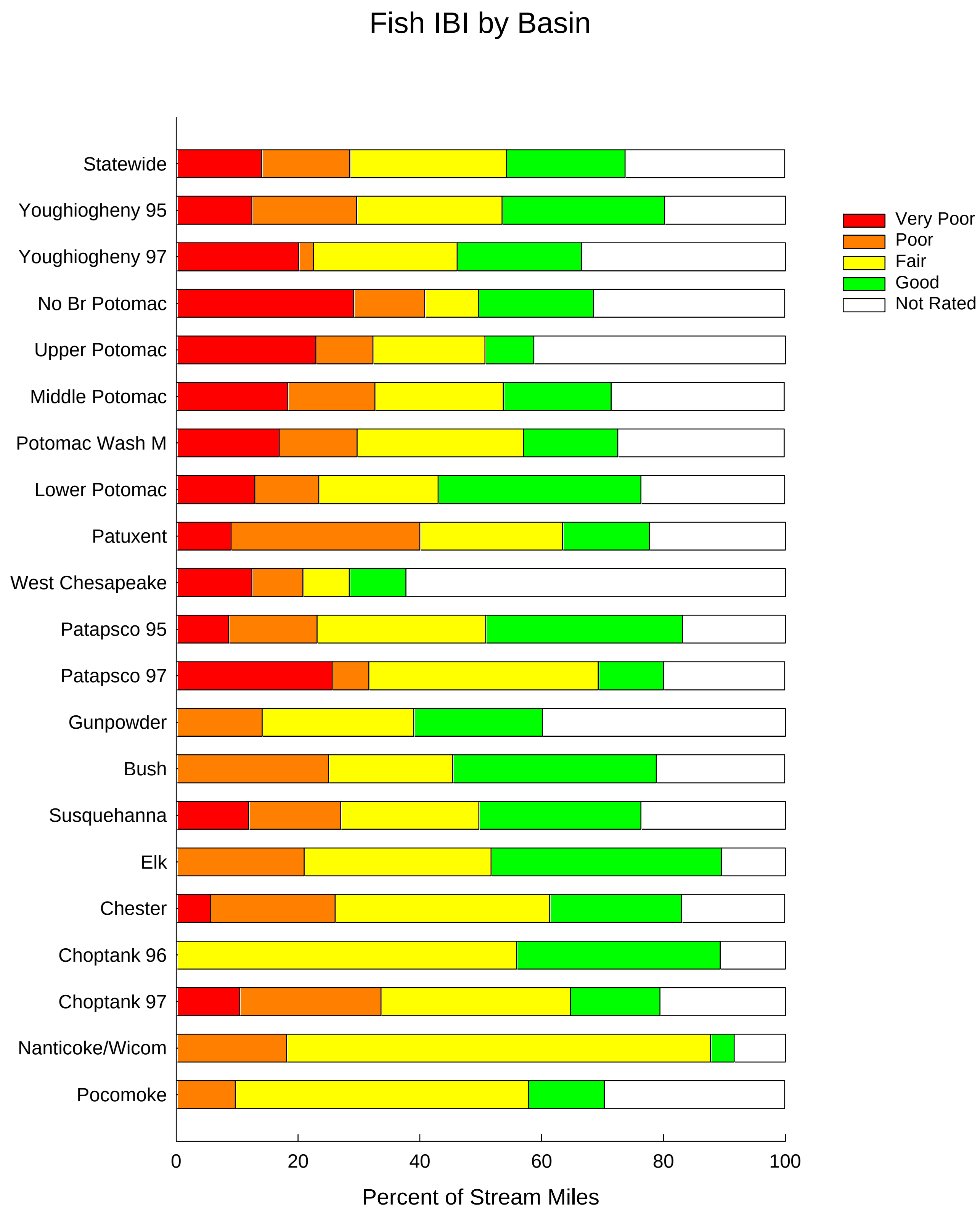


Figure 5-4. Fish Index of Biotic Integrity (IBI) scores for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor. No IBI score was assigned to sites with watershed area < 300 acres.

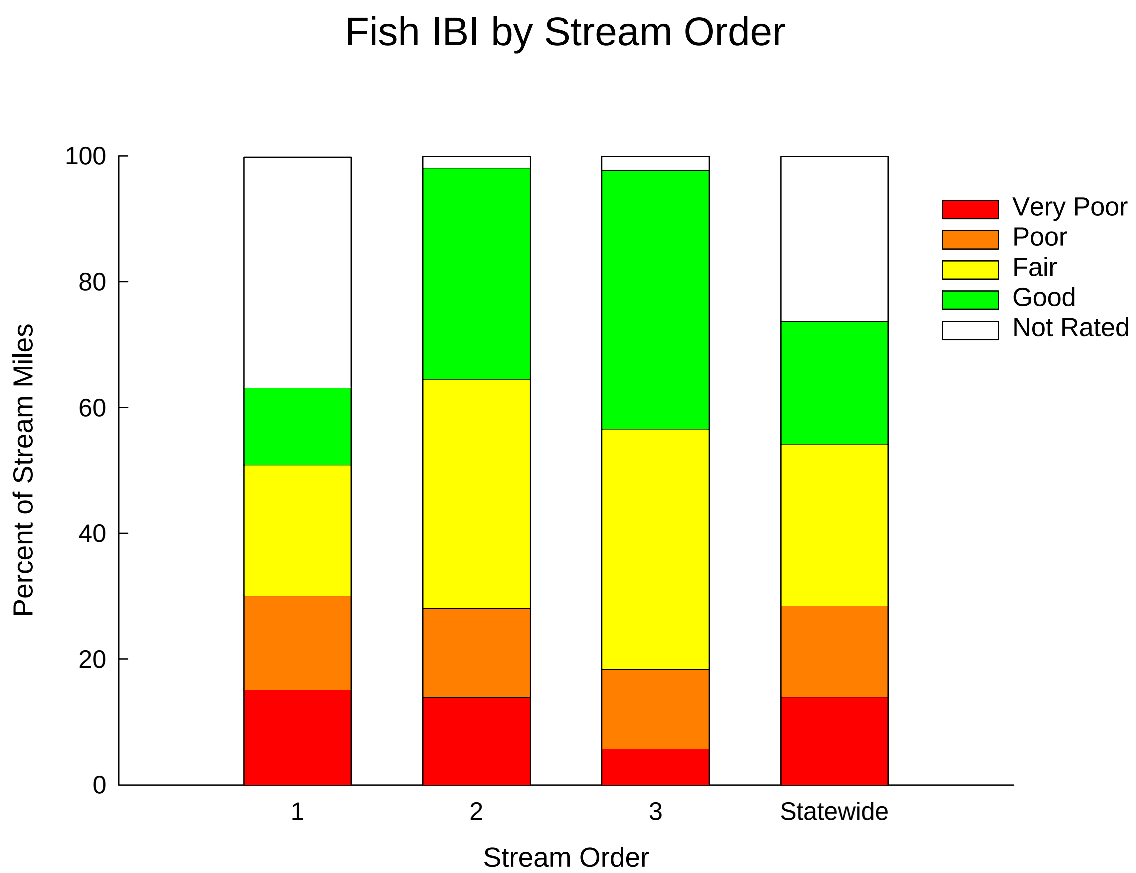


Figure 5-5. Fish Index of Biotic Integrity (IBI) scores by stream order, for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor. No IBI score was assigned to sites with watershed area < 300 acres.

Table 5-6. Estimated percentage of stream miles in each fish IBI category for basins sampled in the 1995-1997 MBSS

	Good	Std. Error	Fair	Std. Error	Poor	Std. Error	Very Poor	Std. Error	% Rated
Basin									
Youghiogheny 1995	26.7	10.6	23.9	9.3	17.2	8.9	12.4	6.9	80.1
Youghiogheny 1997	20.4	8.3	23.6	4.9	2.4	1.8	20.1	9.3	66.5
North Branch Potomac	18.9	6.5	8.8	2.8	11.7	5.8	29.1	8.3	68.6
Upper Potomac	8.0	3.8	18.4	5.3	9.4	2.6	22.9	6.8	58.7
Middle Potomac	18.5	3.8	21.6	4.4	14.7	4.8	18.9	5.4	71.7
Potomac Washington Metro	15.5	4.9	27.0	6.8	12.4	4.8	16.9	6.1	73.7
Lower Potomac	33.3	8.0	19.6	7.6	10.5	5.7	12.9	6.6	76.4
Patuxent	14.3	3.6	23.4	5.7	31.0	6.7	9.0	4.3	77.6
West Chesapeake	9.3	7.9	7.6	2.8	8.4	3.3	12.4	8.2	37.7
Patapsco 1995	32.3	7.6	27.7	7.1	14.5	5.3	8.6	4.9	83.1
Patapsco 1996	10.7	4.0	37.7	7.9	6.0	3.5	25.6	7.4	80.1
Gunpowder	21.1	7.1	24.9	6.3	14.1	6.7	0.0	0.0	60.1
Bush	33.4	12.1	20.4	11.8	25.0	14.6	0.0	0.0	78.8
Susquehanna	26.6	7.0	22.7	9.9	15.1	8.4	11.9	8.1	76.3
Elk	37.8	14.8	30.7	14.8	21.0	14.3	0.0	0.0	89.5
Chester	21.7	8.6	35.2	11.2	20.5	9.7	5.6	5.6	83.1
Choptank 1996	33.4	15.1	55.9	18.7	0.0	0.0	0.0	0.0	89.3
Choptank 1997	14.7	5.1	31.1	16.5	23.2	14.3	10.4	10.3	79.3
Nanticoke/Wicomico	3.9	2.2	69.6	19.1	18.1	11.6	0.0	0.0	91.6
Pocomoke	12.5	9.8	48.1	17.4	9.7	9.7	0.0	0.0	70.4
Stream Order									
1	12.3	7.7	20.8	7.1	14.9	6.2	15.2	8.0	63.2
2	33.6	7.9	36.4	8.6	14.2	5.9	13.9	8.4	98.1
3	41.1	12.1	38.2	10.2	12.6	6.4	5.8	4.8	97.8
Statewide	19.5	7.1	25.7	5.5	14.5	5.0	14.0	7.0	73.8

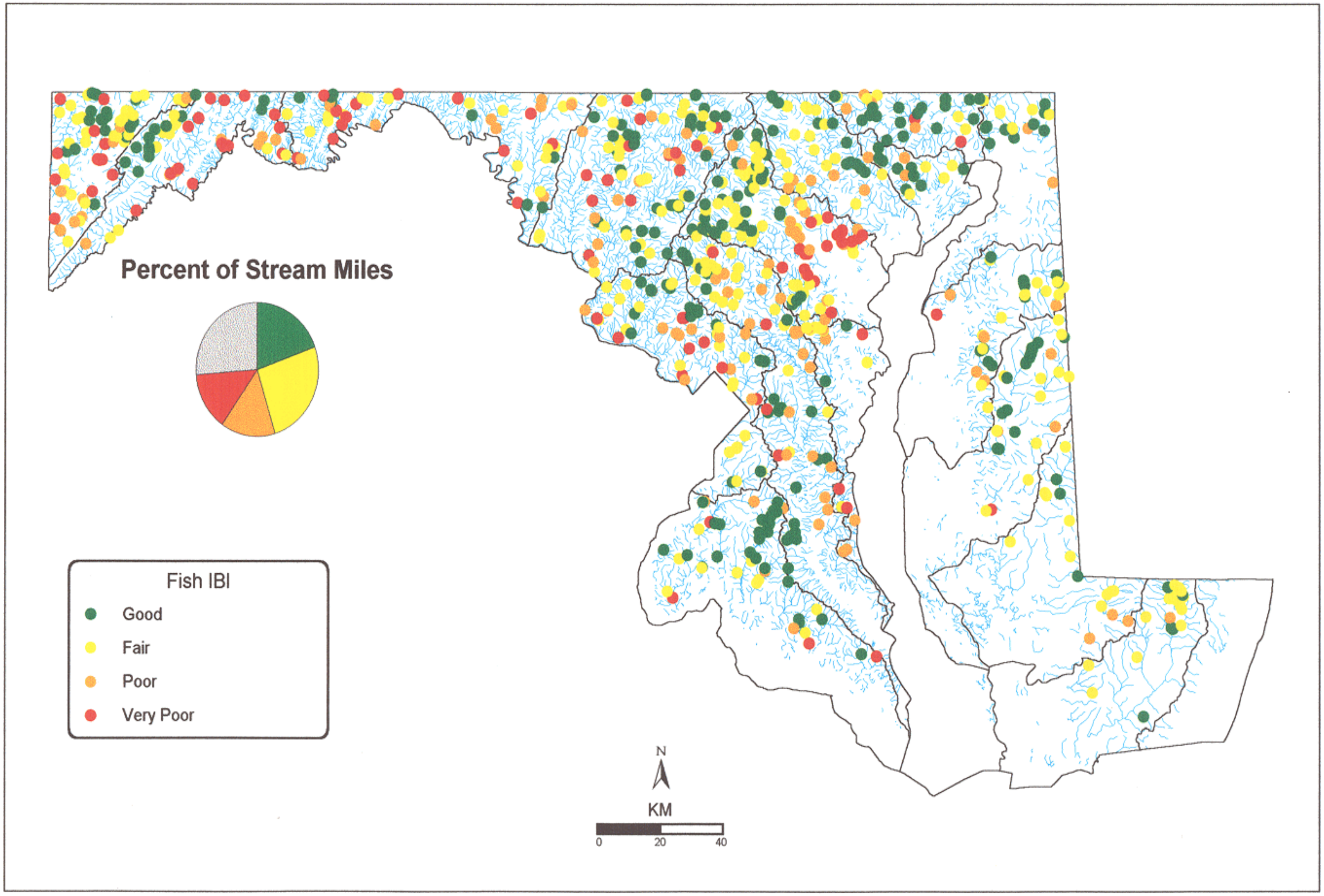


Figure 5-6. Geographic distribution of fish Index of Biotic Integrity (IBI) scores throughout the study area, including the statewide distribution of the percentage of stream miles with fish in each category: 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor. No IBI score was assigned to sites with watershed area < 300 acres.

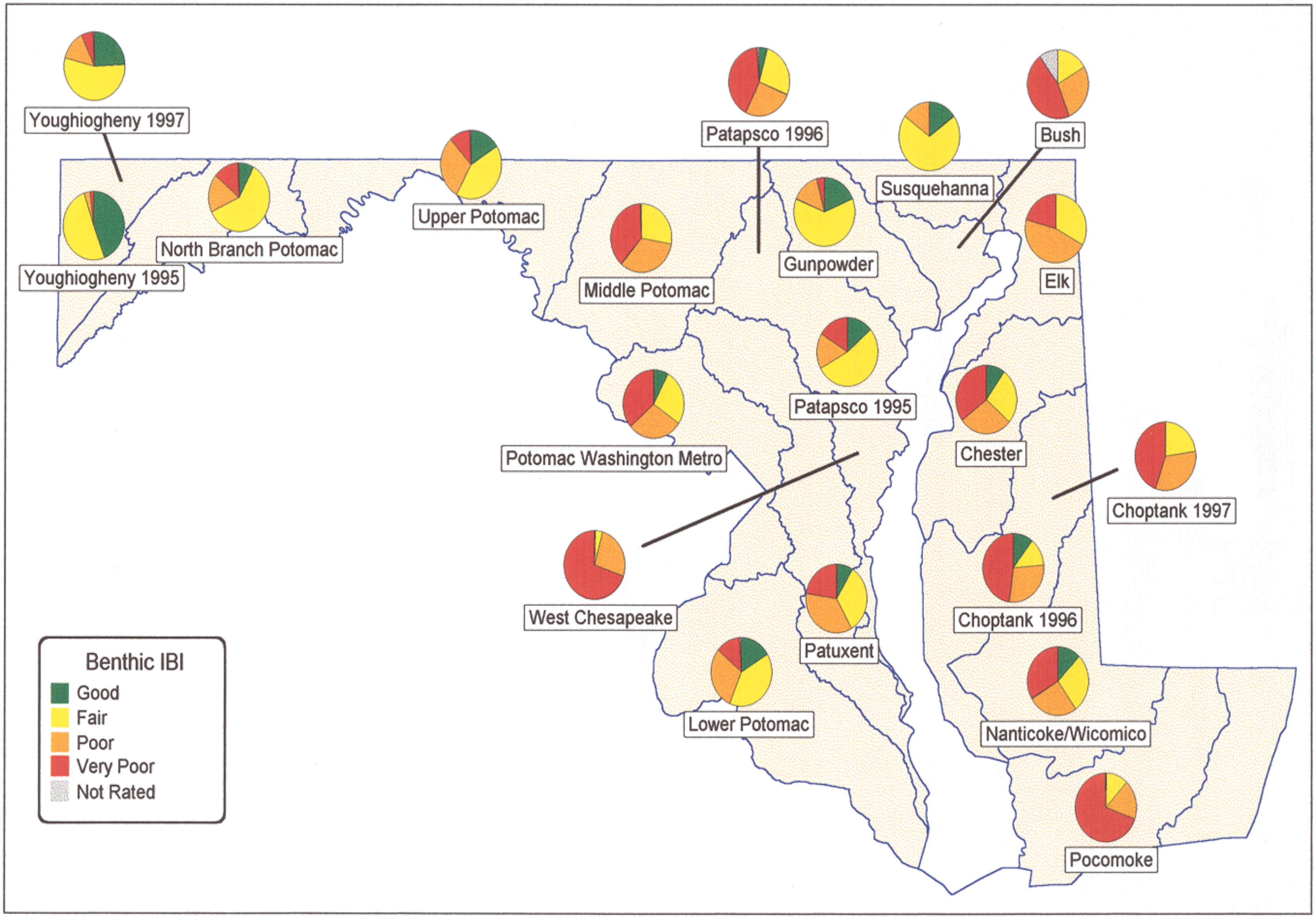


Figure 5-7. Geographic distribution of benthic Index of Biotic Integrity scores for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor

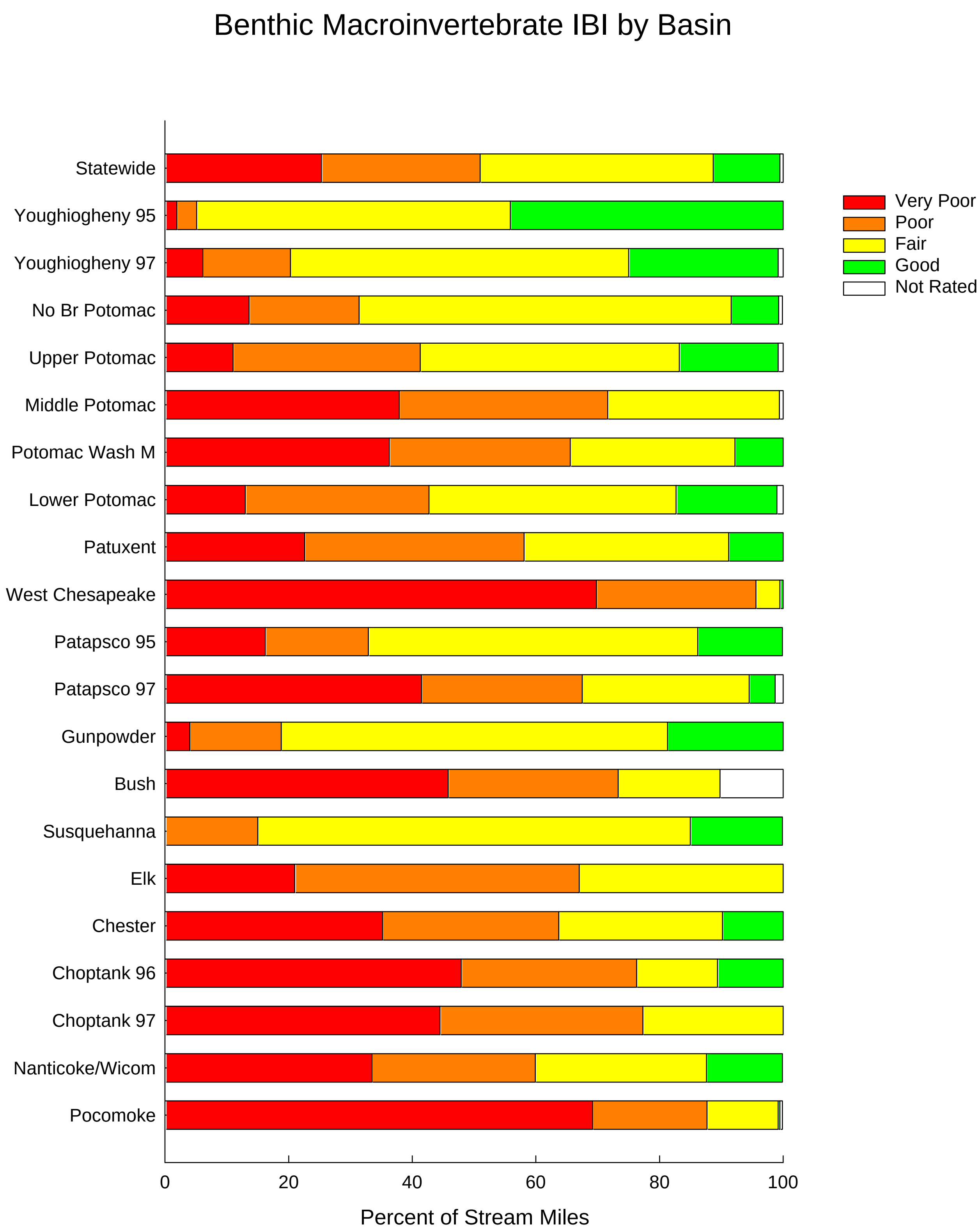


Figure 5-8. Benthic Index of Biotic Integrity (IBI) scores for basins sampled in the 1995-1997 MBSS, as the percentage of stream miles in each category: IBI 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor

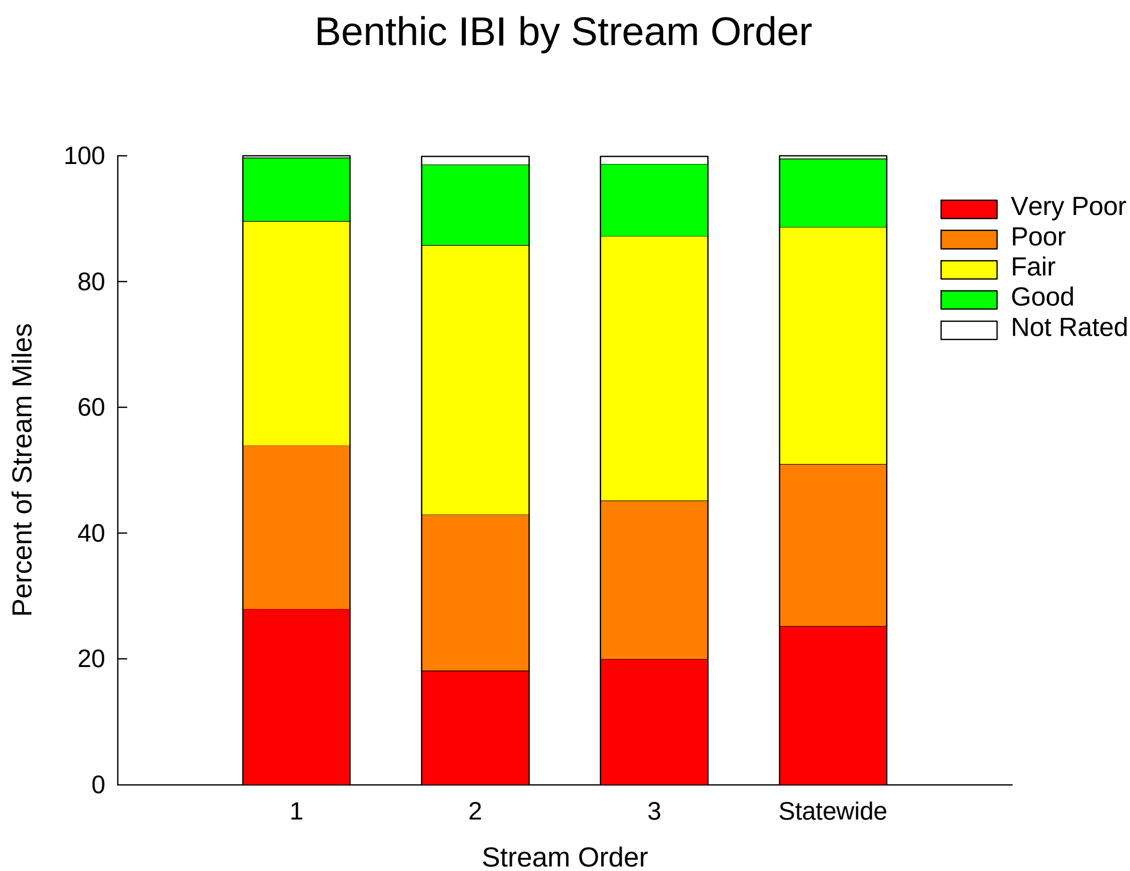


Figure 5-9. Benthic Index of Biotic Integrity (IBI) scores by stream order, for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: IBI 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor

Table 5-7. Estimated percentage of stream miles in each benthic IBI category for basins sampled in the 1995-1997 MBSS									
	Good	**Std. Error**	**Fair**	**Std. Error**	**Poor**	**Std. Error**	**Very Poor**	**Std. Error**	**% Rated**
Basin									
Youghiogheny 1995	44.1	11.1	50.8	11.3	3.2	1.7	1.9	1.0	100.0
Youghiogheny 1997	24.2	9.0	54.7	11.3	14.2	7.5	6.1	5.3	99.2
North Branch Potomac	7.7	3.9	60.2	9.1	17.8	6.3	13.6	5.4	99.4
Upper Potomac	16.0	5.3	41.9	7.7	30.3	7.3	11.0	5.1	99.2
Middle Potomac	0.0	0.0	27.8	6.0	33.7	5.7	37.9	6.7	99.3
Potomac Washington Metro	7.8	4.3	26.6	6.7	29.3	7.4	36.3	7.9	100.0
Lower Potomac	16.3	5.6	40.0	9.3	29.7	8.8	13.0	6.3	99.0
Patuxent	8.8	3.4	33.1	6.4	35.5	6.9	22.6	6.0	100.0
West Chesapeake	0.5	0.5	3.9	1.8	25.8	10.2	69.8	16.8	100.0
Patapsco 1995	13.7	5.9	53.3	9.2	16.7	6.1	16.2	5.5	100.0
Patapsco 1996	4.2	3.3	27.0	7.4	26.0	7.0	41.5	8.2	98.7
Gunpowder	18.7	7.6	62.5	9.8	14.8	6.8	4.0	4.0	100.0
Bush	0.0	0.0	16.5	10.6	27.5	11.8	45.8	16.3	89.8
Susquehanna	14.9	7.9	70.0	11.7	15.0	7.8	0.0	0.0	100.0
Elk	0.0	0.0	33.0	14.8	46.0	17.3	21.0	14.3	100.0
Chester	9.9	5.6	26.5	9.0	28.5	10.5	35.2	11.3	100.0
Choptank 1996	10.6	8.5	13.1	8.5	28.4	12.9	47.9	14.8	100.0
Choptank 1997	0.0	0.0	22.7	10.6	32.8	13.2	44.5	14.2	100.0
Nanticoke/Wicomico	12.3	8.6	27.7	13.8	26.4	13.8	33.5	15.4	100.0
Pocomoke	0.3	0.3	11.5	7.4	18.5	10.1	69.2	14.5	99.7
Stream Order									
1	10.1	6.5	35.6	9.4	26.0	6.8	28.0	11.2	99.7
2	12.8	3.8	42.8	14.7	24.9	6.5	18.1	9.9	98.6
3	11.4	6.2	42.1	9.4	25.2	8.4	20.0	6.9	98.7
Statewide	10.8	5.0	37.7	10.0	25.7	5.5	25.3	9.7	99.4

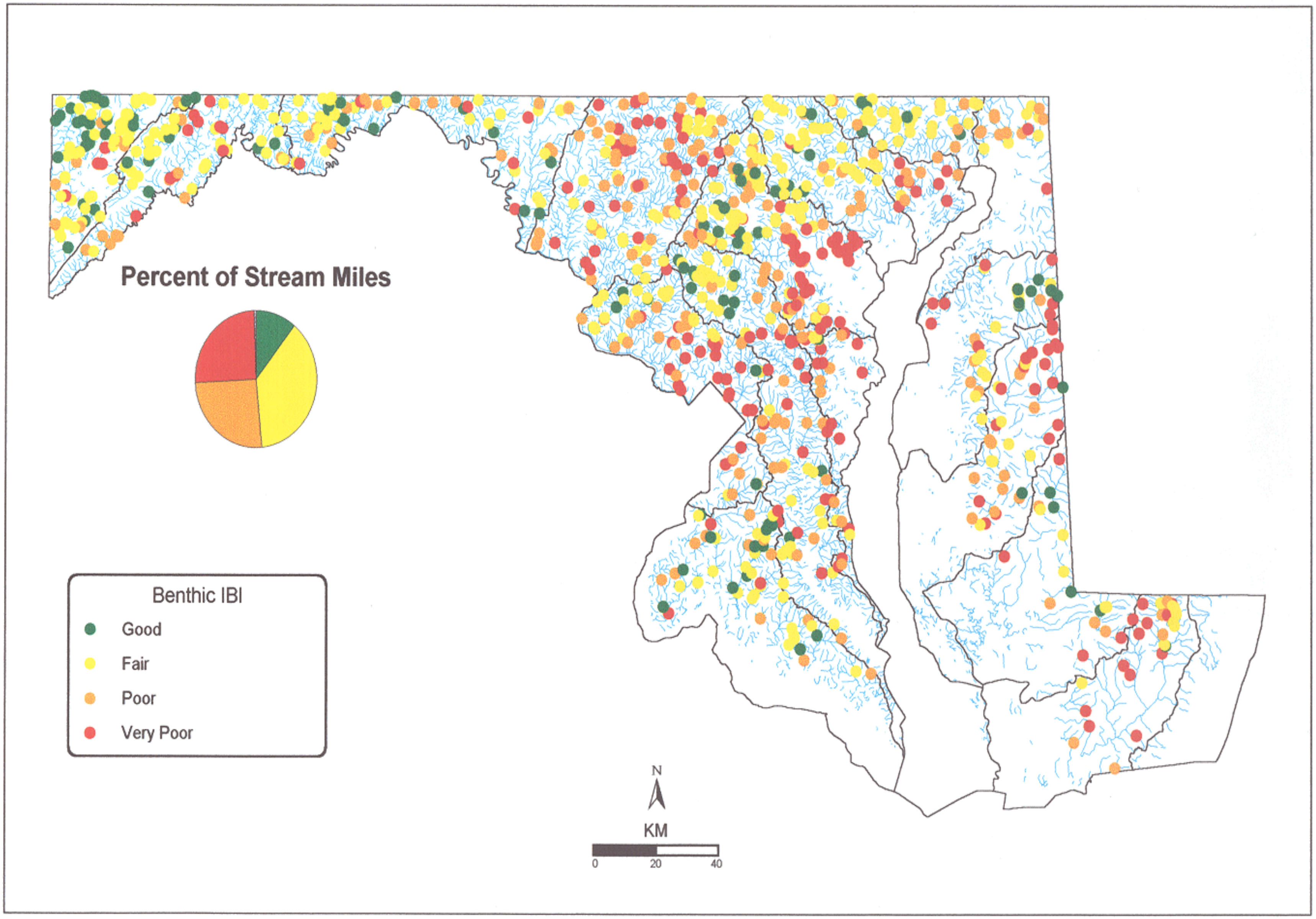


Figure 5-10. Geographic distribution of benthic Index of Biotic Integrity (IBI) scores throughout the study area, including the statewide distribution of the percentage of stream miles with benthic IBI scores in each category

First-order streams sampled throughout the state had a smaller percentage of stream miles in the good and fair categories, and a greater percentage rated very poor, than did larger streams. Again, this may be indicative of more highly impacted conditions in first-order streams.

5.3.3 The Hilsenhoff Biotic Index

The Hilsenhoff Biotic Index (Hilsenhoff 1977, 1987, 1988; Klemm et al. 1990; Plafkin et al. 1989) was also used as an indicator of the biological condition of streams surveyed. The Index evaluates pollution tolerance, primarily tolerance to organic pollution. Hilsenhoff Biotic Index scores tend to increase with degradation. A tolerance value of 0 to 10 is assigned to each taxon collected; the index is calculated as an average tolerance value for the assemblage, weighted by the abundance of each taxon. Currently, tolerance values for Maryland benthic taxa are derived primarily from research in the Midwest (Hilsenhoff 1987), New York (Bode 1988), and North Carolina (Lenat 1993).

Although the Hilsenhoff Biotic Index is most useful for discerning degradation due to organic pollution, and has not been calibrated specifically for Maryland, it provides an additional means of applying threshold values to determine degradation. The original Hilsenhoff scale contained threshold values for six categories of degradation. Bode and Novak (1995) modified this scale to include four categories ranging from non-impacted to severely impacted. For the purposes of this Survey, these four categories were adopted with narrative ratings assigned as follows:

- Scores of 0 to 4.5 are rated good
- Scores of 4.51 to 6.5 are rated fair
- Scores of 6.51 to 8.5 are rated poor
- Scores of 8.51 to 10.0 are rated very poor

Hilsenhoff scores at MBSS sites ranged from 0.41 to 9.97.

Statewide, the greatest percentage of stream miles were in fair condition (42%). An estimated 36% were in good condition, 16% were in poor condition, and 3% were very poor based on the Hilsenhoff Biotic Index. Three percent of stream miles were not rated. Sites were not used in the calculation of the Hilsenhoff Biotic Index if they contained too few individuals for the Index to be meaningful. Seven basins contained stream miles that rated in very poor condition: the North Branch Potomac, Middle Potomac, Patuxent, Patapsco (1996 sampling), Bush, and Choptank (1997 sampling), and the Potomac Washington Metro basin with the highest percentage of stream miles rated as very poor (12%). With the exception of the Pocomoke and the Choptank (1997 sampling) basins, each basin had some stream miles rated as good, with the highest percentage in the 1997 sampling of the Gunpowder basin (88%). Figures 5-11 and 5-12 show the breakdown of Hilsenhoff Biotic Index scores by basin and by stream order.

5.4 COMPARISON OF FISH AND BENTHIC ASSESSMENTS

For the 17 basins sampled during the 1995-1997 MBSS, there was a significant linear relationship between fish IBI scores and benthic IBI scores, although there was a large amount of variation when data from all basins were pooled (linear regression, $p < 0.001$, $r^2=0.12$). When basins were examined individually, there was a significant linear relationship between fish IBI and benthic IBI in nine of the basins sampled ($r^2=0.11$ to 0.42). For example, the Patapsco basin showed a relationship between the fish and benthic IBI (Figure 5-13; $r^2=0.34$). In this basin, sites that had low fish IBI scores also had low benthic IBI scores. There are several likely reasons for the differences between the fish IBI and the benthic IBI results. The first is that the different IBI scores may reflect different responses to stressors (i.e., pollution or physical habitat degradation) by the two groups of organisms. For example, fish are more mobile than benthic organisms and may be better able to temporarily avoid a stress upon stream water quality. Fish can live in a wide variety of habitats, so some of the low benthic IBI scores may reflect natural conditions where prime benthic habitat (e.g., well-aerated riffles) does not exist. In other situations, benthos may be more directly affected by habitat degradation that causes sedimentation or even movement of unstable substrates. Finally, due to small watershed size, 98 sites were not rated for the fish IBI. All of these sites were assigned benthic IBI scores (the majority of which were rated poor or very poor), resulting in differences in the percentages of stream miles in each IBI category. In a comparison of results at all sites statewide, fish and benthic IBI scores for the same site were most often within 1.0 IBI unit of one another. The fish IBI tended to be slightly higher than the benthic IBI, particularly in second- and third-order streams. Regional differences did not appear to explain differences, as these results were consistent across all regions (Coastal Plain, Piedmont, and Highland).

For the 17 basins there was also a significant linear relationship between fish IBI scores and the Hilsenhoff Biotic Index, although there was a large amount of variation when data from all sampled basins were pooled

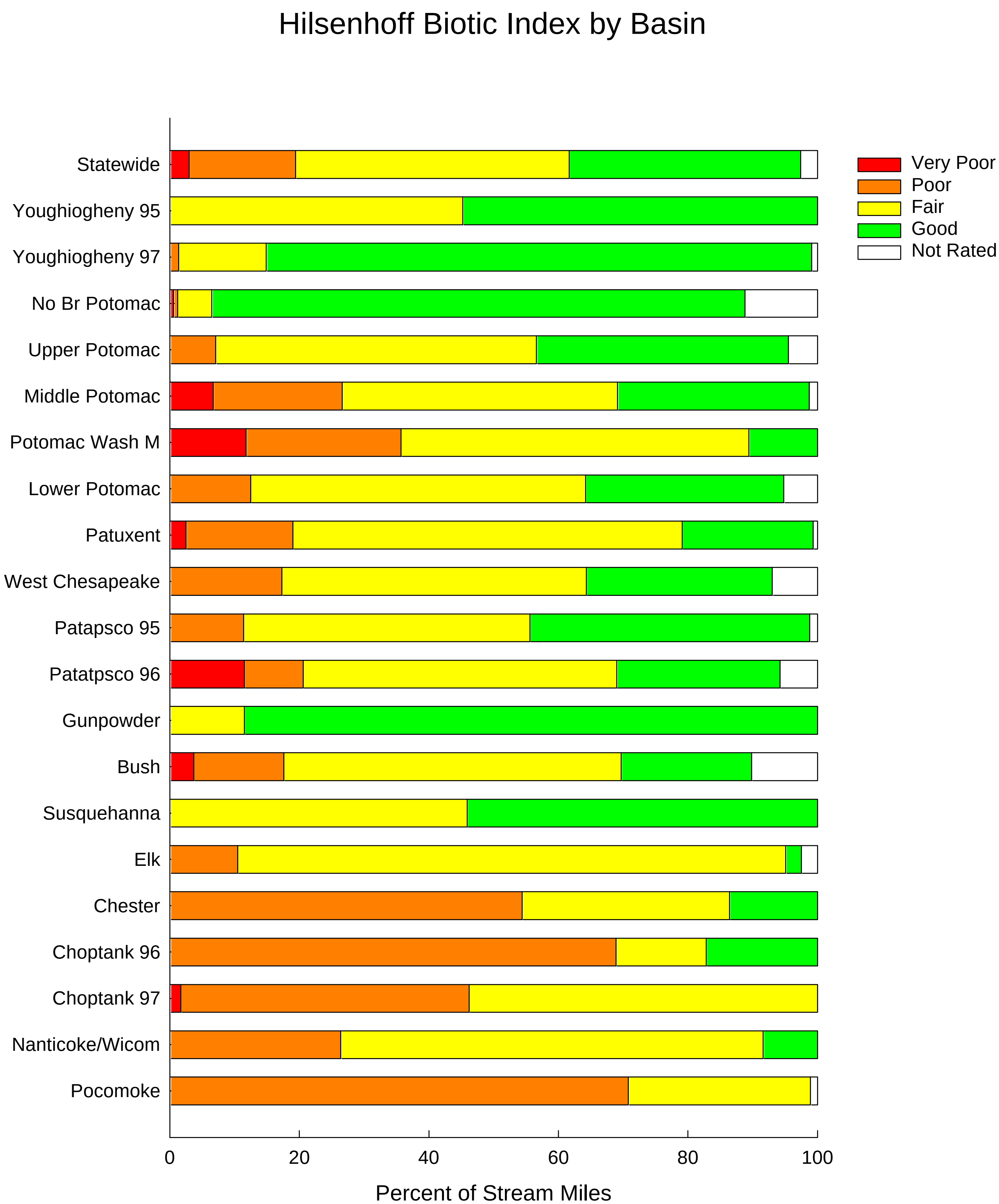


Figure 5-11. Hilsenhoff Biotic Index scores for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 0 - 4.5 good, 4.51 - 6.5 fair, 6.51 - 8.5 poor, and 8.51 - 10.0 very poor

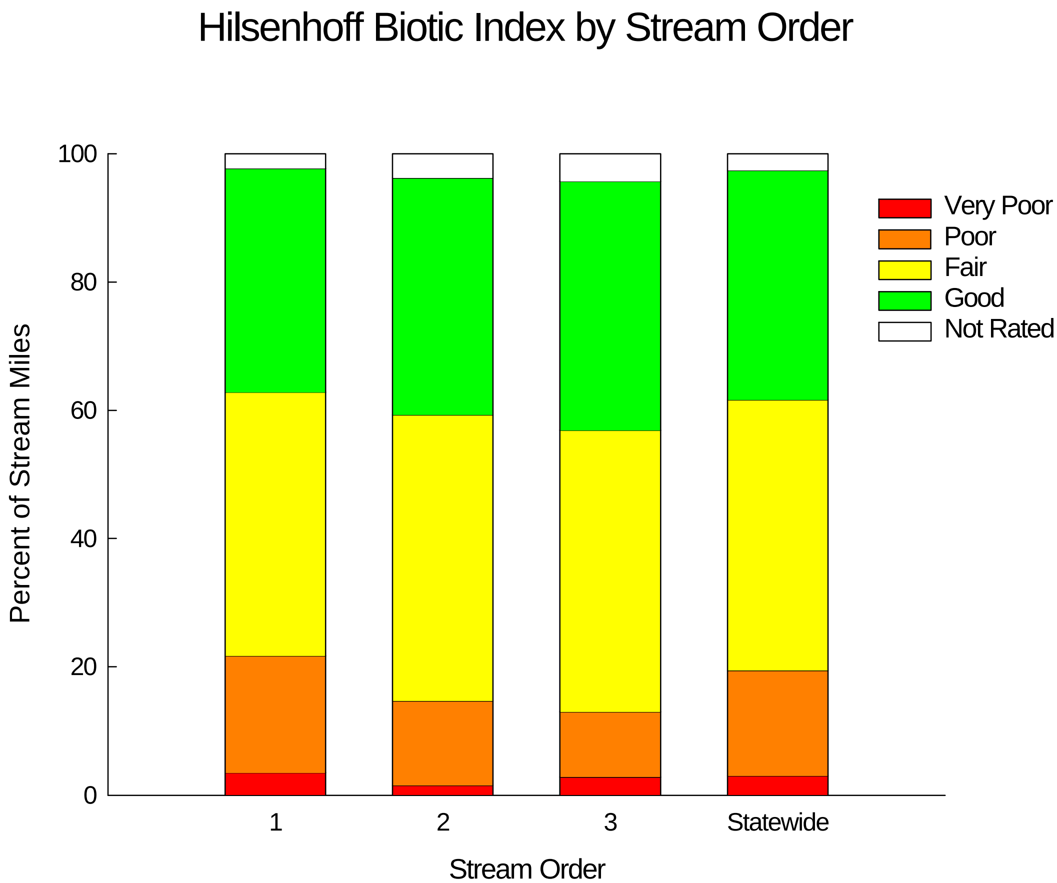


Figure 5-12. Hilsenhoff Biotic Index scores by stream order, for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 0 - 4.5 good, 4.51 - 6.5 fair, 6.51 - 8.5 poor, 8.51 - 10.0 very poor

(linear regression, $p<0.001$, $r^2=0.021$). As expected, this relationship was a negative one, given that IBI scores decrease with increased degradation while Hilsenhoff scores increase. When basins were examined individually, there was a significant linear relationship between fish IBI and Hilsenhoff Biotic Index in eight of the basins sampled ($r^2=0.05$ to 0.49).

It was expected that there would be a relationship between the benthic IBI and the Hilsenhoff Biotic Index, as both measure the quality of the benthic invertebrate community in a stream. A significant linear relationship does indeed exist between the two indicators for all basins sampled (linear regression, $p < 0.001$, $r^2=0.35$). Again, the relationship was a negative one given that IBI scores decrease with degradation while Hilsenhoff scores increase. When basins were examined individually, there was a significant linear relationship between benthic IBI and Hilsenhoff Biotic Index in 13 of the basins sampled ($r^2=0.13$ to 0.74). For example, there was a relatively strong relationship in the Patuxent basin (Figure 5-14; $r^2=0.42$). In general, sites in this basin that had low benthic IBI scores also had high Hilsenhoff Biotic Index scores.

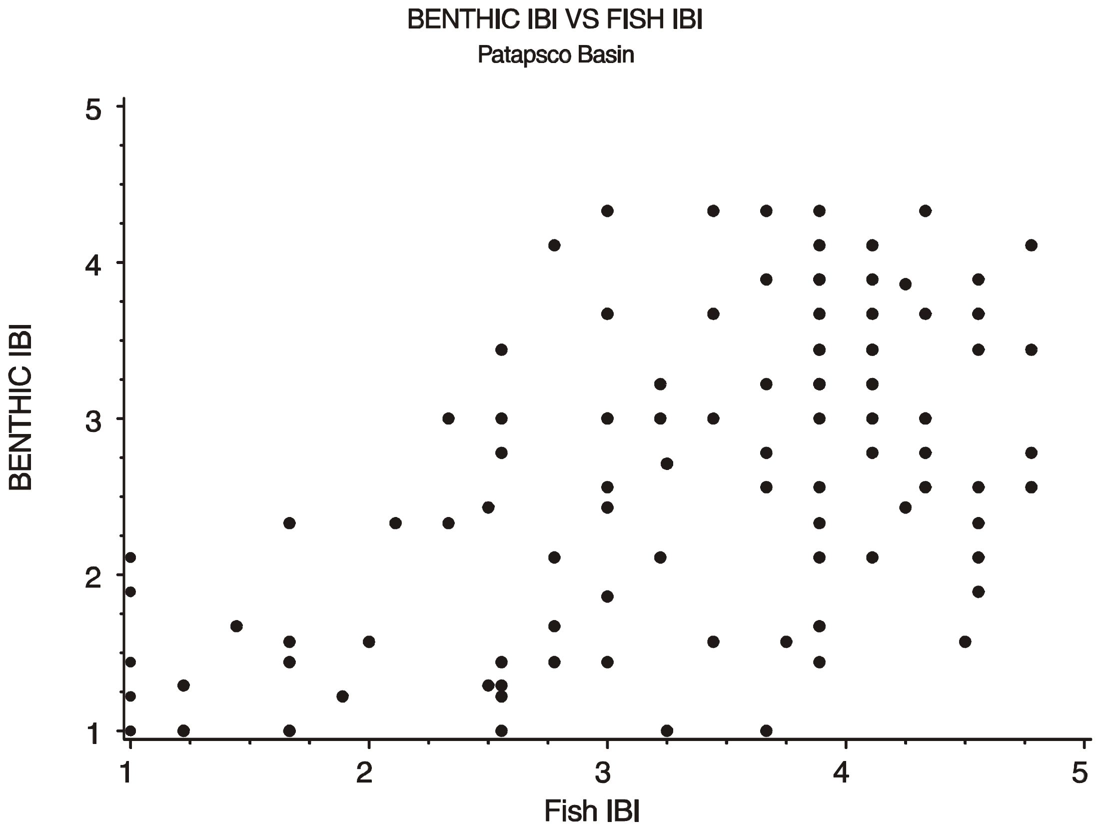


Figure 5-13. Relationship between fish IBI and benthic IBI for the Patapsco basin (linear regression, $p < 0.001$, $r^2=0.34$)

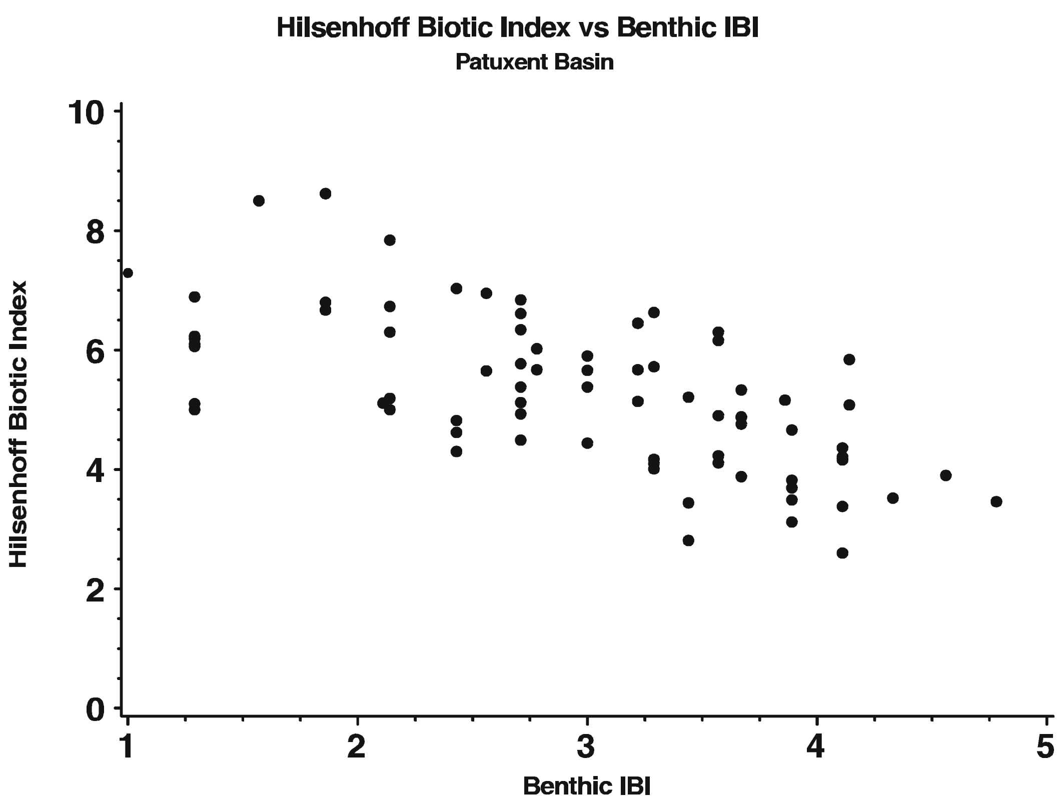


Figure 5-14. Relationship between benthic IBI and Hilsenhoff Biotic Index for the Patuxent basin (linear regression, $p < 0.001$, $r^2=0.42$)

6 ACIDIFICATION

One of the primary objectives of the 1995-1997 Maryland Biological Stream Survey (MBSS or Survey) is to assess the effect of acidic deposition on the biological resources of Maryland streams. Acidification is known to have detrimental effects on fish and other aquatic biota (Baker and Christensen 1991), both from direct effects of low pH and through toxic effects resulting from increases in heavy metal concentrations (e.g., aluminum and mercury) that leach from the soils. Because the Survey collects both biological and water chemistry data, it has the ability to measure not only the extent of acidification in Maryland but also the extent of potential impacts on aquatic biological communities. This chapter examines statistical relationships between acidification and biological condition in benthic macroinvertebrate, fish, and amphibian and reptile communities.

6.1 BACKGROUND

The effects of acidic deposition on stream chemistry are well documented. Maryland's 1987 Synoptic Stream Chemistry Survey (MSSCS; Knapp et al. 1988) concluded that approximately one-third of all headwater streams in Maryland are sensitive to acidification or are already acidic. Research has demonstrated that the vulnerability of stream systems to acidic deposition depends on watershed hydrology and the ability of the vegetation, soils, and bedrock within the watershed to buffer acidic inputs.

The defining characteristics of surface waters sensitive to acidification are low to moderate pH and acid neutralizing capacity (ANC). pH is a measure of the acid balance of a stream. The pH scale ranges from 0 to 14, with pH 7 as neutral. Low to moderate pH ($\leq$ 6) signifies high acidity. ANC is a measure of the capacity of dissolved constituents in the water to react with and neutralize acids and is used as an index of the sensitivity of surface water to acidification. The higher the ANC, the more acid a system can assimilate before experiencing a decrease in pH. Repeated additions of acidic materials can cause a decrease in ANC. In many acidic deposition studies (e.g., Schindler 1988), an ANC of 200 μeq/l is considered the threshold for defining acid-sensitive streams and lakes.

Alternatively, a stream's sensitivity to acid deposition can be measured using "indicator organisms" that are selected as representatives of community health. In a recent study of acid deposition impacts in Maryland streams (Janicki et al. 1991), the sensitivity of an indicator species was expressed as the critical pH at which half or more of the population experiences acute or chronic effects. The level of acid deposition which results in the critical pH is known as the "critical load." In the critical loads study, information on soil buffering ability was combined with MSSCS ANC values to estimate critical loads at specific sites across the state. Critical load results revealed wide differences in the sensitivity of Maryland streams in different provinces:

- The Appalachian Plateau, Coastal Plain and portions of the Blue Ridge are very sensitive (critical load values < 0.5 keq SO_4/ha/year or 24 kg SO_4/ha/year).

- In contrast, the Valley and Ridge, Piedmont, and portions of the Blue Ridge regions exhibit critical loads well over 2.0 keq SO_4/ha/year (96 kg SO_4/ha/year). These are areas where limestone bedrock and derived soils are prevalent.

These critical loads values provided the basis for a reassessment of acidic deposition in 1998 (Miller et al. 1998). When measured sulfate deposition was compared with critical loads, the results suggested that streams continue to be impacted in some areas of the State despite recent reductions in industrial sulfate emissions, a finding consistent with stream chemistry measured in the 1995-1997 MBSS.

Acidification is known to cause declines in both the diversity and abundance of fish populations. Current evidence indicates that the number of aquatic taxa in an ecosystem usually declines with increasing acidity (Eilers et al. 1984, Mills and Schindler 1986, Stephenson and Mackie 1986). In a review of pH effects on aquatic biota, Baker and Christensen (1991) report a number of critical thresholds at which certain fish populations are affected. Many streams in Maryland have pH values below critical levels, with critical pH values for inland species ranging from 5.0 to 6.5 (Baker et al. 1990a; Morgan et al. 1991). For instance, several bass and trout species have a reported critical threshold of pH 5.0-5.5, while a number of more sensitive cyprinid and darter species are adversely affected at pH 5.5-6.0. Acid-tolerant species, such as the yellow perch *(Perca flavescens),* can survive at pH levels of 4.5 or lower. Eastern mudminnow (*Umbra pygmaea*) have been found in waters with pH 4.0 or lower (Jenkins and Burkhead 1993).

The primary mechanisms for fish population declines under acidic conditions include both recruitment failure (owing to increased mortality of early life stages) and direct effects on adult survival. One of the physiological effects observed when pH decreases is the disruption of the normal internal ionic salt balance, which causes the fish to lose salt to the surrounding water. If the salt losses exceed intake, fish go into shock, lose equilibrium and eventually die. Acidic waters can also inhibit the development of fish reproductive organs and facilitate the development of a mucous that suffocates eggs and fry (Eno and Di Silvestro 1985). The loss of entire fish populations in abnormally acidic streams or lakes usually occurs because of successive failures in the reproductive cycle. Other detrimental effects are caused by the increased concentrations of metal ions that result from acidification (e.g., from the leaching of aluminum and the formation of methylmercury).

In addition to potential long-term (chronic) acidification, streams in Maryland are susceptible to rapid, short-term increases in acidity (episodic acidification) related to precipitation, snow melt, and stormflow events (Greening et al. 1989; Gerritsen et al. 1992; Wigington et al. 1993). One study estimates that 50% more streams in the northern Appalachian Plateau of Western Maryland probably experience the deleterious effects of episodic acidification than are chronically acidified (Eshleman 1995). Spatial and temporal variability of acidic conditions are important to the magnitude of effects on aquatic biota. For example, a pulse of episodic acidification during juvenile recruitment could have a greater effect on a fish population than it would at other times of the year. The highest levels of acidity in Maryland streams have been recorded in the spring, when many fish, including economically important anadromous fish species of the Chesapeake Bay, enter the freshwater portions of coastal streams to spawn. Large-scale fish kills frequently result when snow melts and large quantities of acidic materials are released into rivers and streams (Eno and Di Silvestro 1985).

Because many invertebrate taxa are also sensitive to acidification, detrimental effects on food webs may occur well before direct toxicity to fish is evident (Schindler et al. 1989, Gill 1993). Benthic invertebrate taxa richness may be reduced as a result of acidification (Ford 1988). Often some taxa are lost as a result of acidity, but this loss may be compensated for by an increase in numbers of acid-tolerant species, resulting in little or no decrease in overall biomass (Eriksson et al. 1980, Dixit and Smol 1989). Several invertebrate taxa— notably mollusks, crustaceans, leeches, mayflies, some species of water striders, caddisflies, damselflies, dragonflies, and cladocerans— are sensitive to acidification and become scarce or disappear between pH 5.0 and 6.0 (Havas and Hutchinson 1982, Eilers et al. 1984, Raddum and Fjelheim 1984, Ormerod and Tyler 1986, Bendell 1988, Bendell and McNicol 1987).

The Survey provides an opportunity to examine the influences of acidic deposition on fishes and other biota in non-tidal streams. Results from the 1995-1997 MBSS sampling are presented below.

6.2 EXTENT OF THE ACIDIFICATION PROBLEM

6.2.1 Low pH

In evaluating the influence of acidification on stream biological communities, it is important to determine the extent and distribution of acidic and acid-sensitive streams. During spring sampling, an estimated 2.6% of the stream miles across the 17 basins sampled in the 1995-1997 MBSS had pH less than 5, while another 6.4% had pH 5-6 (Figure 6-1). Low spring pH was most common in the Pocomoke basin, where about 34% of stream miles had pH less than 5 and 28% of stream miles had pH 5-6. Summer field sampling results were similar: across the 17 basins an estimated 1.8% of the stream miles had pH less than 5, while 4.1% had pH 5-6. Of the 17 basins sampled in the MBSS, 10 experienced low pH during summer sampling and 13 did during spring sampling. The lowest summer pH was observed in the North Branch Potomac basin, where about 16% of the stream miles had summer pH less than 5 and 1% had summer pH 5-6 (Figure 6-2).

Small streams, particularly first-order streams, appeared to be most susceptible to low pH conditions, with the highest percentage of stream miles in the low pH classes. None of the third-order sites sampled had spring pH < 5. During spring, only 2.7% of third-order stream miles had pH 5-6, compared to 8.4% of first-order stream miles. Likewise, only 1.6% of third-order stream miles sampled in summer had pH <6, compared to 7.3% of first-order stream miles.

6.2.2 Low Acid Neutralizing Capacity (ANC)

Although pH is the most commonly used measure of acidification, ANC is a better overall measure of acidification and acid sensitivity, because it also indicates which systems are likely to become acidified under episodic conditions. The following critical ANC values were used to characterize streams according to acid sensitivity: < 0 μeq/l (acidic), $0 \leq$ ANC < 50 μeq/l (highly sensitive to acidification), $50 \leq$ ANC < 200 μeq/l (sensitive to acidification), and ≥ 200 μeq/l (not sensitive to

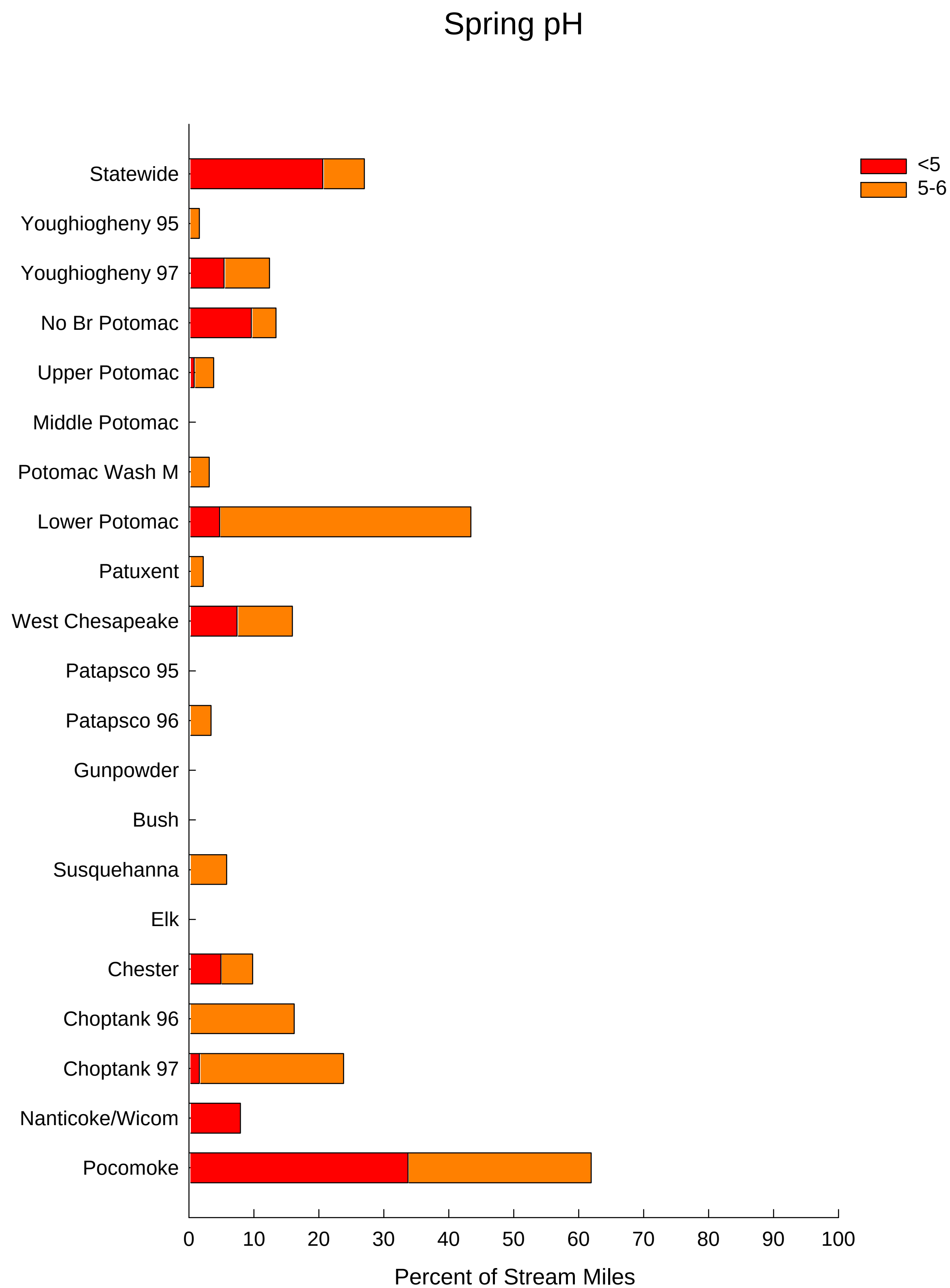


Figure 6-1. Percentage of stream miles with low pH by basin (spring pH), for basins sampled in the 1995-1997 MBSS

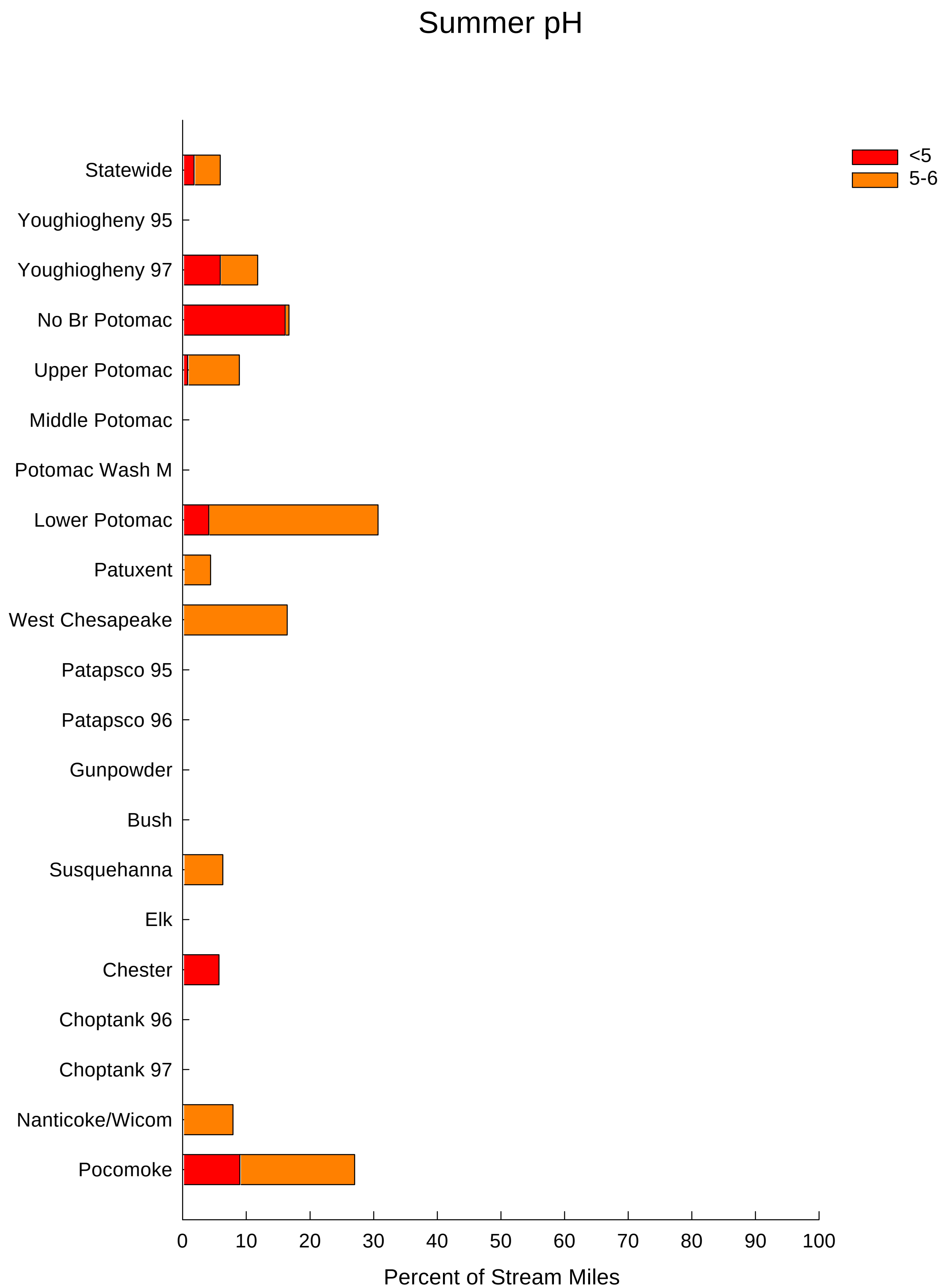


Figure 6-2. Percentage of stream miles with low pH by basin (summer pH), for basins sampled in the 1995-1997 MBSS

acidification). A number of questions about stream acidification can be answered with MBSS results. Statewide, an estimated 28% of the stream miles were acidic or acid-sensitive, including about 2% acidic, 4% highly sensitive, and 22% sensitive to acidification. Five basins had greater than 50% of stream miles with ANC < 200: the Lower Potomac (79%), Pocomoke (66%), North Branch Potomac (64%), Youghiogheny (63% in 1997 sampling), and Choptank (62% in 1996 sampling). The Susquehanna and Patapsco basins had no sites with ANC < 200. The percentage of acid sensitive, highly sensitive, and acidified stream miles in each basin is shown in Figure 6-3.

Statewide, the estimated percentage of stream miles with ANC < 0 was 3% of first-order stream miles, 2% of second-order, and 0% of third-order stream miles. The estimated percentage of stream miles with ANC < 200 was 31% of first-order, 21% of second-order, and 20% of third-order stream miles.

6.3 SOURCES OF ACIDITY

In estimating the extent of acidification of Maryland streams, it is important to understand how acidic deposition, acid mine drainage, agricultural runoff, and natural organic materials contribute to the observed acidification. Acidic deposition is the contribution of material from atmospheric sources, both as precipitation (wet) and particulate (dry) deposition. Acidic deposition is generally associated with elevated concentrations of sulfate and nitrate in precipitation. Acid mine drainage (AMD) results from the oxidation of iron and sulfur from mine spoils and abandoned mine shafts and is known to cause extreme acidification of surface waters. Streams strongly impacted by AMD exhibit high levels of sulfate, manganese, iron, and conductivity. A third source of acidification is surface runoff from agricultural lands that are fertilized with high levels of nitrogen or other acidifying compounds. Lastly, the natural decay of organic materials may contribute acidity in the form of organic anions, as in blackwater streams associated with bald cypress wetlands. Streams dominated by organic sources of acidity are often characterized by high concentrations of dissolved organic carbon (DOC > 8 mg/l) and organic anions. Water chemistry data may be analyzed to distinguish among the four sources of acidity potentially affecting sites in the 17 basins sampled in the 1995-1997 MBSS.

Sources of acidification in Maryland streams have been examined in previous DNR studies using water chemistry data from the MSSCS and other regional surveys. In a study of Maryland Coastal Plain streams, Janicki (1991) reported a predominance of low ANC conditions and found that differences in stream chemistry within the region were related to land use. In particular, ANC tended to be higher in watersheds dominated by agriculture. Agricultural activities in Coastal Plain watersheds can have different effects on stream chemistry, adding both ANC (from soil liming practices) and strong acid anions (from nitrogen fertilizers) (Janicki et al. 1995). Janicki and Wilson (1994) estimated that acidic deposition was the dominant source of acidity in about 45% of the low ANC streams in the Maryland Coastal Plain, while combined inputs from acidic deposition and agricultural sources affected about 55% of the streams. In Maryland's Appalachian Plateau and Blue Ridge regions, where there are also a significant number of acidic and acid-sensitive streams, bedrock geology was an important factor in determining stream response to acidic deposition, according to analyses by Janicki (1995). Atmospheric deposition was identified as the major source of acidification in the Appalachian Plateau and Blue Ridge streams. Organic acids and agricultural sources did not appear to be major contributors to acidification in Western Maryland streams. The analyses by Janicki (1995) did not include effects of acid mine drainage.

For the MBSS, a new analysis was conducted to estimate the extent of impacts by acidic deposition, acid mine drainage, agricultural runoff and organic sources. Water chemistry data from sites with low ANC (< 200 μeq/l) were examined to identify dominant sources of acidification (Figure 6-4) and to estimate the percentage of stream miles impacted by each. Results were compared by river basin, because different acidity sources were expected to be important in the eastern and western parts of the State.

Instream concentrations of sulfate and nitrate ions are important indicators of acid sources. For areas near the ocean, however, analyses of stream chemistry need to account for contributions of sulfates from airborne sea salts. In our analysis, measured instream sulfate concentrations were corrected for sea salt influence, which decreases with distance from the coast. The amount of marine sulfate is related to levels of marine chloride, which can be estimated from a site’s distance from the coast. Because the MBSS does not directly measure chloride concentrations, estimates of sea salt sulfate and chloride concentrations were made using the following relationships derived for Mid-Atlantic streams by the National Stream Survey (Baker et al. 1990b, Kaufmann et al. 1992):

$$\ln(Cl^-_{sea}) = 5.4328 - 0.0180 \cdot Dist + 0.00004 \cdot Dist^2$$

$$\text{sea salt corrected } SO_4 = SO_4^{2-}{}_{(observed)} - 0.013 \cdot Cl^-_{sea}$$

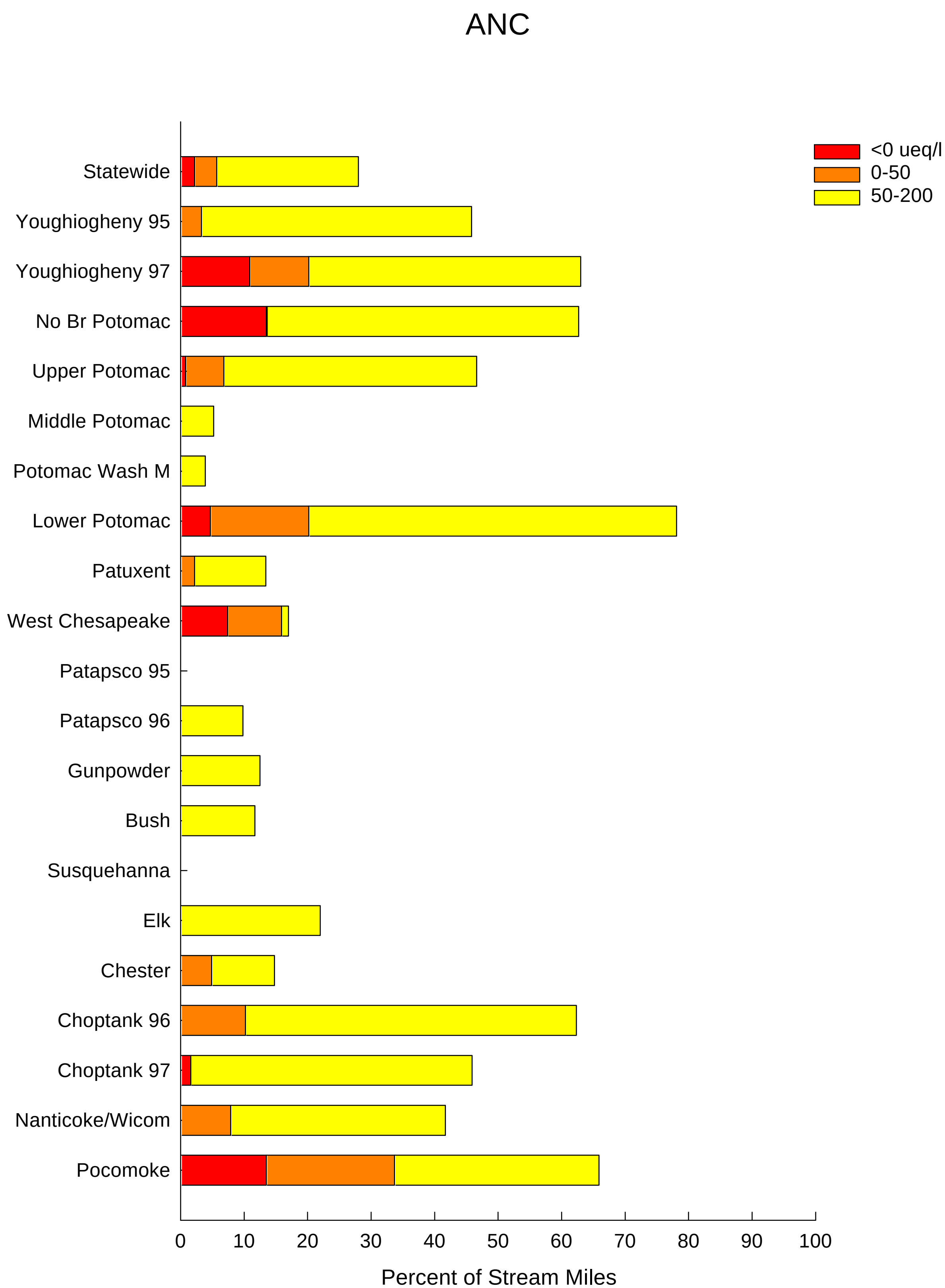


Figure 6-3. Percentage of stream miles with low ANC by basin, for basins sampled in the 1995-1997 MBSS. ANC classes are in μeq/l.

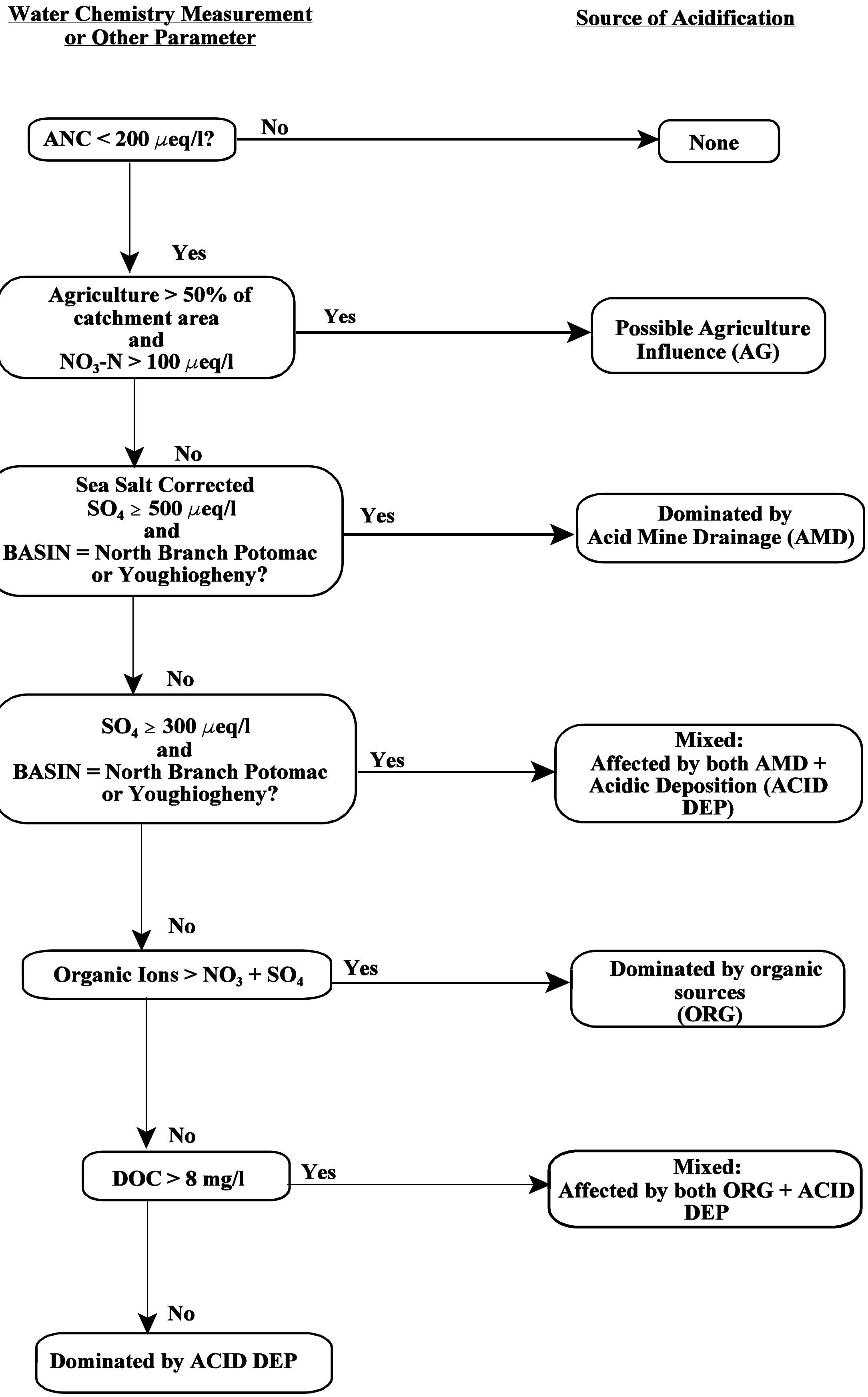


Figure 6-4. Procedure for the determination of acid sources for sites sampled in the 1995-1997 MBSS

where Cl^-_{sea} = concentration of sea salt derived chloride (μeq/l), Dist = distance from the coast (km), and $SO_4^{2-}{}_{(observed)}$ = observed sulfate concentration (μeq/l). The sea salt correction was made only for MBSS sites within 200 km of the ocean. Beyond 200 km, streams are assumed to have no sea salt contributions (Baker et al. 1990b).

In Western Maryland streams, sulfate concentrations were used to distinguish MBSS sites having AMD as the dominant source of acidification from those dominated by acidic deposition. Based on results of previous studies in Mid-Atlantic Highlands streams (Kaufmann et al. 1992, Herlihy et al. 1990), thresholds were established to distinguish which sites were affected by AMD. For all sites in the Youghiogheny and North Branch Potomac River basins with ANC less than 200 μeq/l, those with sulfate concentrations greater than 500 μeq/l were designated as dominated by AMD. Sites with sulfate in the 300-500 μeq/l range were considered affected by both AMD and acidic deposition.

Ancillary field evidence of mine influence was recorded for each site in the 1995-1997 MBSS and used as an independent data set to assess the accuracy of the AMD classification. This included field observations and other known evidence of past or present mine activity or of AMD problems, as identified by the Western Maryland field crew leader (Kline 1998, personal communication). The presence of mine evidence at a site is important because it can be a source of physical degradation even where AMD does not occur. For instance, 6 sites in the Survey showed field evidence of mine influence but had ANC values > 200 μeq/l. Among the 18 sites that were classified as AMD-dominated (using water chemistry), 11 showed conclusive visual evidence of mine influence, 1 showed possible influence, and 6 showed no evidence of mine influence. Among the 15 sites that were classified as AMD and acidic deposition influenced, none showed conclusive visual evidence of mine influence, 9 showed possible influence, and 6 showed no evidence of mine influence. For those sites that were classified as AMD-dominated, sulfate concentrations ranged from 526 to 10,831 μeq/l.

To evaluate the influence of natural organic acids or fertilizers, organic anion concentrations were calculated for all sites from measured concentrations of dissolved organic carbon (DOC) and pH, using methods developed by Oliver (1983). Sites with ANC < 200 μeq/l were screened for organic acidity as the dominant source of acid influence. If organic anion concentrations at a site were greater than the total concentration of nitrate and sea-salt corrected sulfate, organic acids were considered the dominant source of acidification (Kaufmann et al. 1992). Sites with low organic anion concentrations (less than the sum of nitrate and sulfate concentrations) and high DOC values (> 8mg/l) were considered affected by both organic anions and acid deposition. This technique provides a more accurate assessment of organic acidity than is possible using DOC values alone.

High nitrate levels (especially in excess of sulfate levels) often indicate agricultural influence. All sites with ANC < 200 μeq/l were screened for agricultural influence using criteria developed specifically for the MBSS. Correlations among nitrate nitrogen concentration, upstream land use and ANC were examined for thresholds that could be used as classification criteria. A general threshold at approximately 50 percent agricultural land use was observed across Maryland, above which the concentration of nitrate increased in response to agriculture (Figure 6-5). An additional criteria for nitrate-nitrogen (NO_3-N >100 μeq/l or 1.4 mg/l) was selected based on previous assessments to exclude agricultural sites with low nitrate-nitrogen values. These criteria were combined to screen all sites with ANC < 200 μeq/l and to identify those most likely influenced by agricultural sources of acidity (Figure 6-4).

These assigned categories of acid sources were used to estimate the extent of each source affecting Maryland streams. As stated above, an estimated 28% of the total stream miles had ANC < 200 μeq/l. The extent of various acid sources are summarized in Figure 6-6. Acidic deposition was by far the most common source of acidifying compounds, being the dominant source at about 19% of stream miles. AMD was the dominant source at only 1.8% of stream miles, while an additional 1% of stream miles were likely affected by both acidic deposition and AMD. Only 0.8% were dominated by organic sources, while another 1.7% were likely affected by both organic acids and atmospheric deposition. Agriculture accounted for the acidification of 4.2% of all stream miles.

As expected, acid sources varied considerably among basins (Figures 6-6 and 6-7). In the Lower Potomac basin, for example, acidic deposition was the only source of acidity, and accounted for the acidification of 79% of stream miles. Acidic deposition was the only source of acidity in the Elk, Patuxent, and West Chesapeake basins. Ten other basins also showed evidence of acidic deposition.

Acid mine drainage was only present in the North Branch Potomac and Youghiogheny basins. In the North Branch Potomac basin, the extent of AMD effects where significant. Results indicate that 20% of stream miles in the

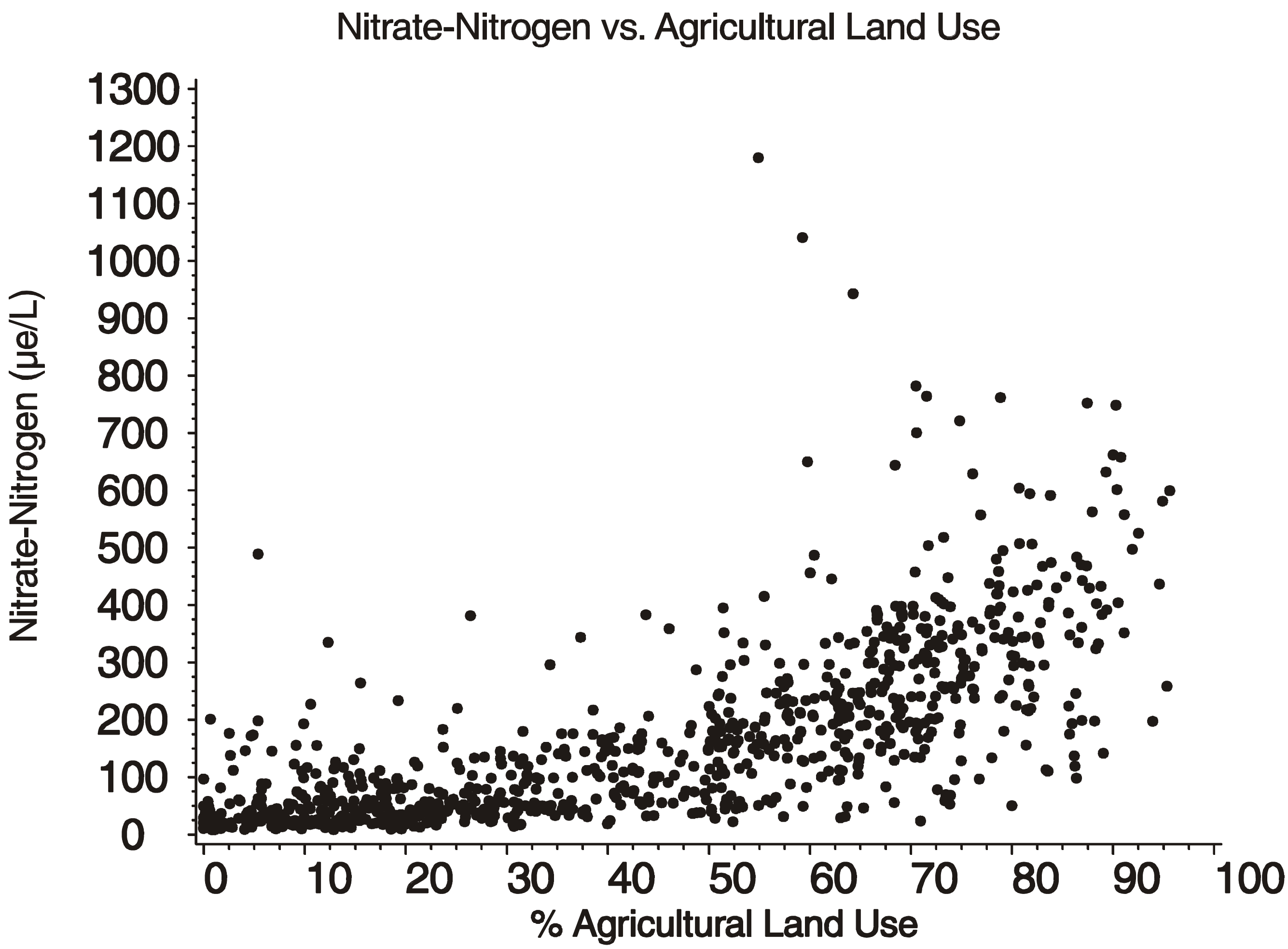


Figure 6-5. Relationship between nitrate-nitrogen (NO_3-N) and the percentage of agricultural land use for the basins sampled in the 1995-1997 MBSS

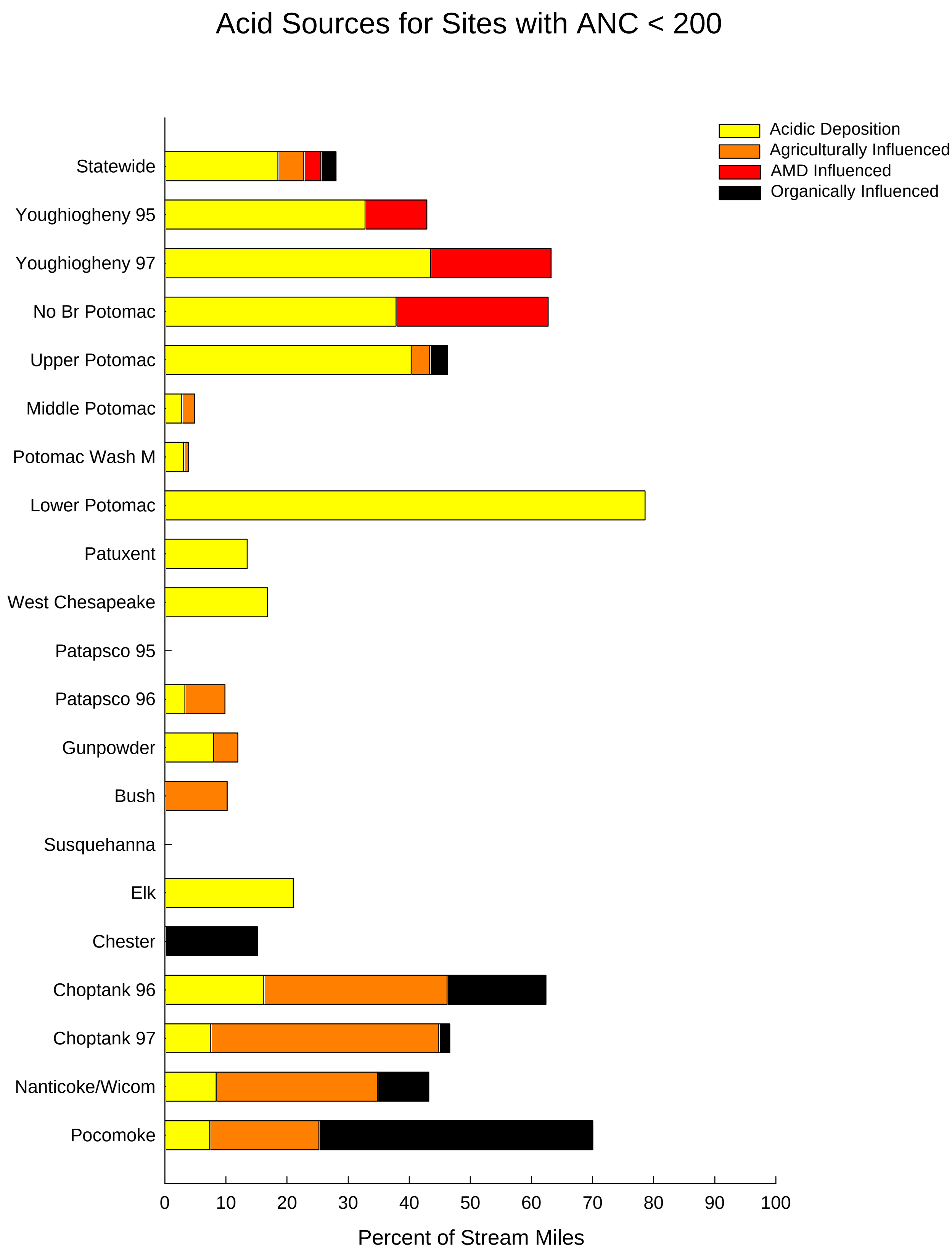


Figure 6-6. Percentage of stream miles with ANC < 200 μeq/l, by acid source for the basins sampled in the 1995-1997 MBSS. The category "AMD Influenced" includes sites affected by AMD and by both AMD and acidic deposition. The category "Organically Influenced" includes sites affected by organic sources and by both organic sources and acidic deposition.

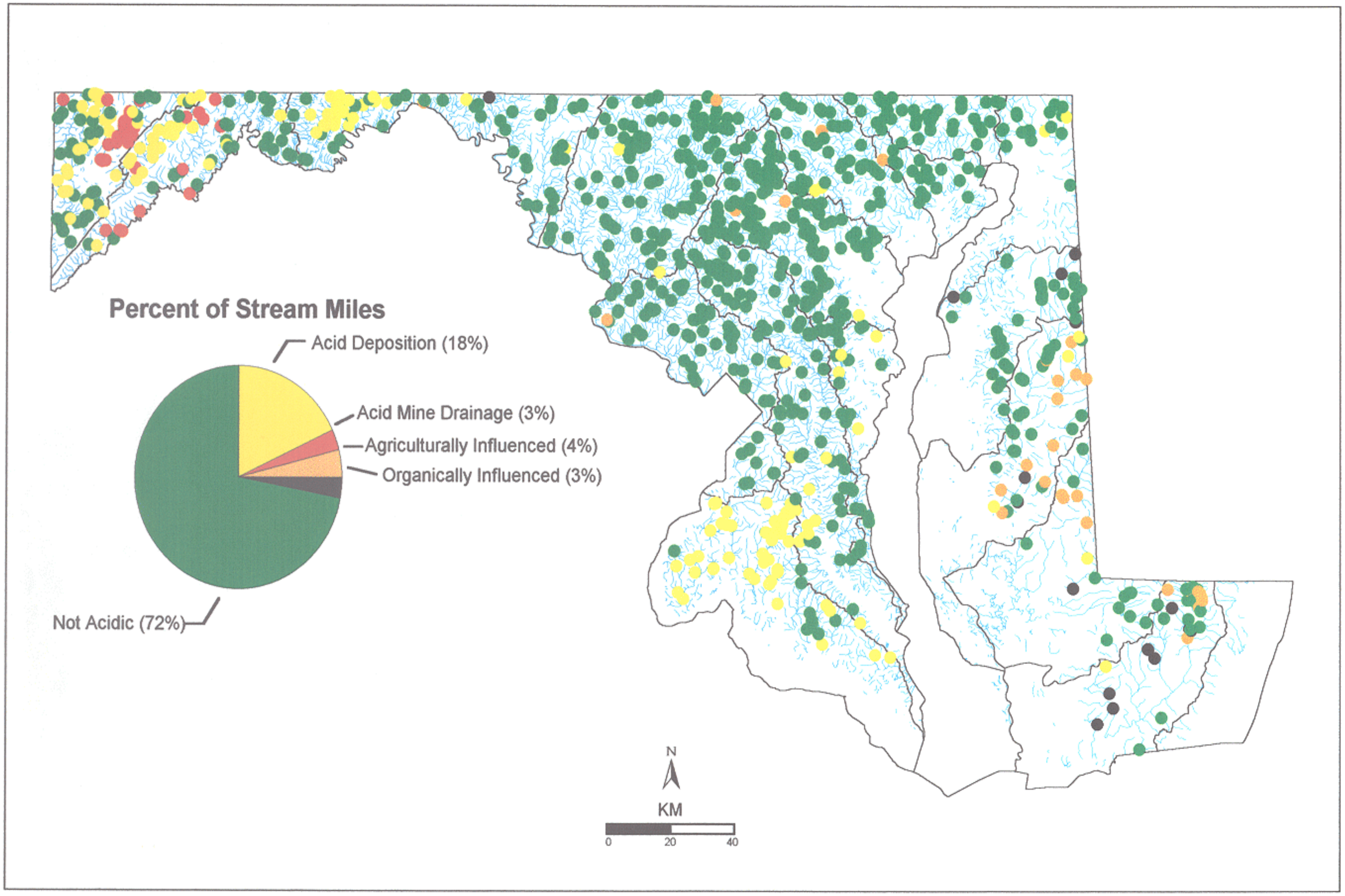


Figure 6-7. Acid sources at 1995-1997 MBSS sites

North Branch Potomac basin were affected by AMD as the dominant source, 5% were likely affected by both AMD and acidic deposition, and another 38% were dominated by acid deposition. In contrast, AMD was the dominant source for only 2% of stream miles in the Youghiogheny basin in 1995, and 11% in 1997. The combined influence of acidic deposition and AMD affected an estimated 8% of Youghiogheny stream miles in 1995 and 8% again in 1997. Another 33% of stream miles in that basin were dominated by acidic deposition in 1995, and 43% in 1997.

Statewide, only four sites (less than 1% of all stream miles) were dominated by organic sources and less than 2% of all stream miles showed combined organic and acidic deposition influences. The small number of organically dominated and influenced sites led to large standard errors (s.e. > 100%) in estimating the number of stream miles that were organically influenced. Fourteen sites had DOC > 10 mg/l, a level commonly used to characterize blackwater streams (streams rich in organic material and typically acidic due to natural sources). However, 10 of these sites had levels of nitrate and sulfate high enough to indicate a strong influence of acidic deposition. Organic anions influenced or dominated the stream chemistry of 44.7% of stream miles in the Pocomoke basin, as well as 16.2% in the Choptank, 15.1% in the Chester, and 8.4% in the Nanticoke/Wicomico basin. Organic acidification also contributed to extreme acidification (ANC < 0) in the Choptank and Pocomoke basins, but only for a small number of sites.

Across the State, 32 sites or 4.2% of acid affected stream miles were classified as agriculturally influenced. Agricultural influences on acidity were most extensive in Eastern Shore basins, accounting for 30% to 37% of stream miles in the Choptank (1996 and 1997 sampling), 26% in the Nanticoke/Wicomico, and 19% of stream miles in the Pocomoke basin. Smaller percentages were observed in the Patapsco, Bush, Gunpowder, Potomac Washington Metro, Middle Potomac, and Upper Potomac basins. Agriculture was rarely responsible for extreme acidification: only one agriculturally influenced site had an ANC < 50 μeq/l, the rest had values of 51-200 μeq/l. High nitrate concentrations were frequently accompanied by high DOC values.

The distribution of acid sources by stream order showed some differences in sources for higher order streams. The frequency of acid sources by stream order across Maryland is summarized in Figure 6-8. Acidic deposition, for example, influenced 23% of all first-order stream miles, but only 16% of all third order stream miles. Agricultural acid sources were associated with 6% of first-order stream miles, but only about 1% of second- and third-order stream miles. AMD affected about 2% of first-order and 5% of third-order stream miles. These results should be interpreted carefully: sources that occurred in less than 2% of stream miles tended to have standard errors of 100% or more.

Subpopulation analyses were done to estimate the percentage of stream miles within low ANC classes (ANC < 200 µeq/l) that were associated with each acid source. The percentage of low-ANC stream miles across the State influenced by each acid source is shown in Figure 6-9. Among streams with ANC < 200, acidic deposition was the dominant source in approximately 66% of stream miles, AMD was the dominant source in 6% of stream miles, and another 4% were affected by both acidic deposition and AMD. Agriculture accounted for the acidification of 15% of stream miles, while organic acids influenced 3% and another 6% were influenced by both organic acids and acidic deposition. Among chronically acidic streams (12 sites with ANC < 0), AMD was the dominant source in 38% of stream miles and acidic deposition was dominant in 42%. Organic acids influenced 9% of chronically acidic streams, while another 11% were influenced by both organic anions and acidic deposition. No sites with ANC < 0 were influenced by agriculture. The higher percentage of AMD-dominated stream miles reflects the presence of highly acidified sites in the North Branch Potomac and Youghiogheny basins.

In the North Branch Potomac and Youghiogheny basins, the subpopulation estimates for streams with ANC < 200 were slightly different from statewide estimates, indicating the greater prevalence of AMD in these basins. Among North Branch Potomac streams with ANC < 200, acidic deposition was the dominant source in approximately 60% of stream miles; AMD was the dominant source in 31% of stream miles; and 8% were affected by both acidic deposition and AMD. Among Youghiogheny streams sampled in 1995 with ANC < 200, acidic deposition was the dominant source in approximately 76% of stream miles; AMD was the dominant source in 5% of stream miles; and 19% were affected by both acidic deposition and AMD. Results for the Youghiogheny for 1997 were consistent with those from 1995. These results indicate that acidic deposition was by far the most common source affecting Maryland streams (ANC < 200 μeq/l), but that AMD was the source most often associated with extreme acidification (ANC < 0 μeq/l) within the North Branch Potomac and Youghiogheny basins.

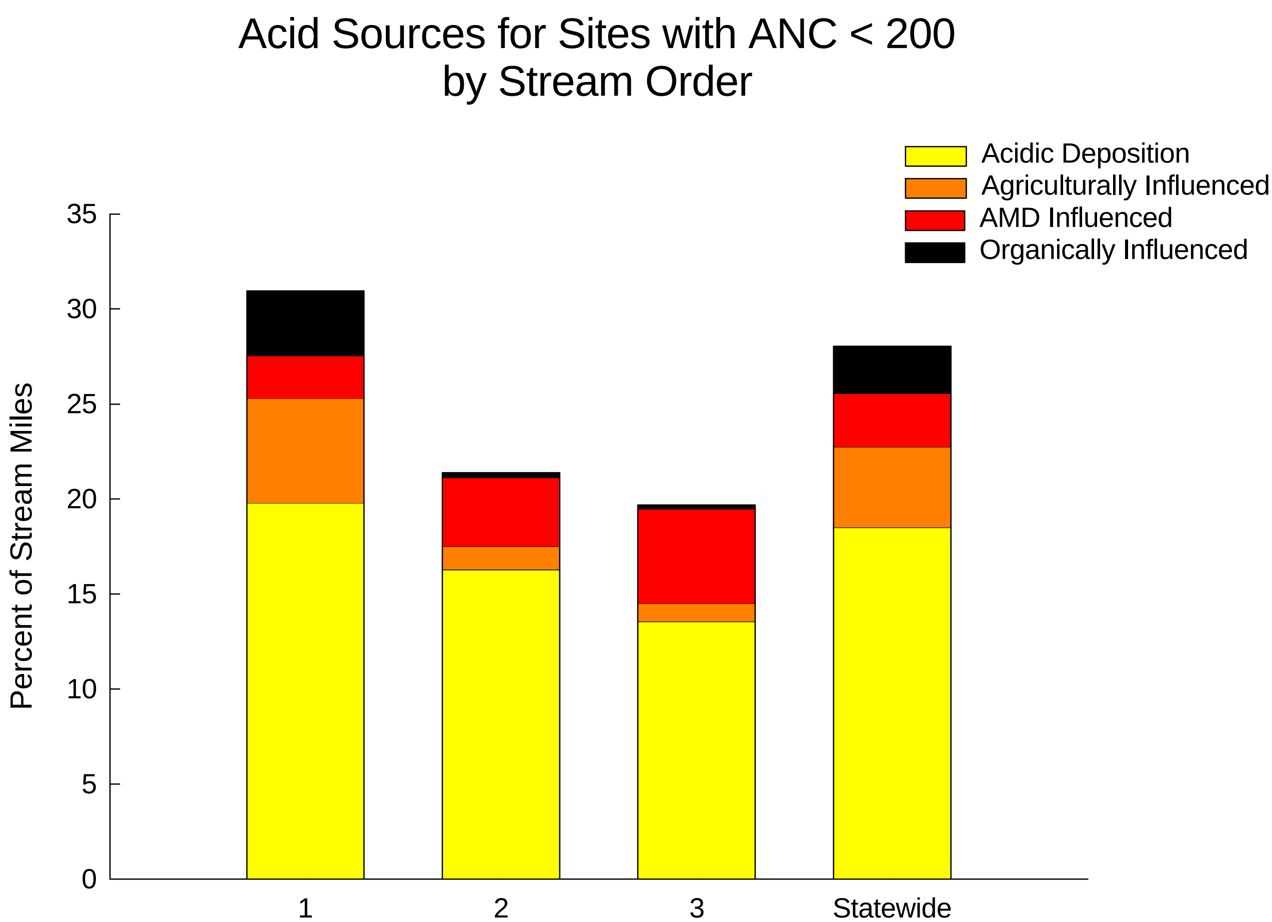
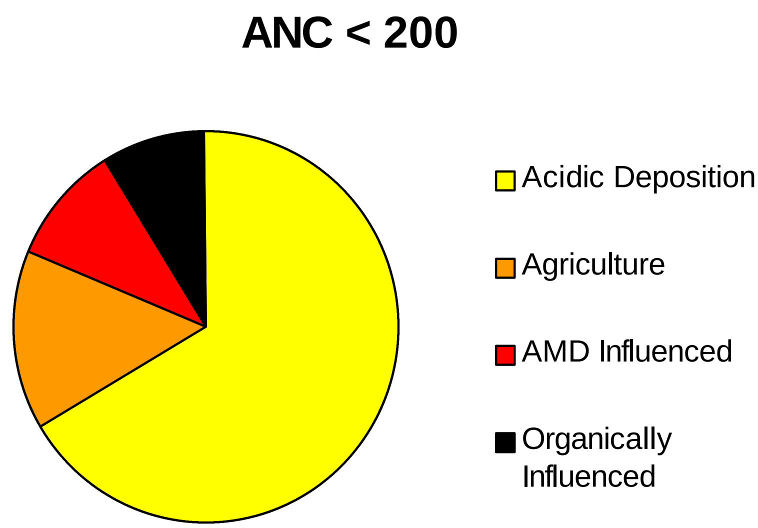


Figure 6-8. Percentage of stream miles with ANC < 200 μeq/l by acid source, by stream order for the 1995-1997 MBSS. The category "AMD Influenced" includes sites affected by AMD and by both AMD and acidic deposition. The category "Organically Influenced" includes sites affected by organic sources and by both organic sources and acidic deposition.



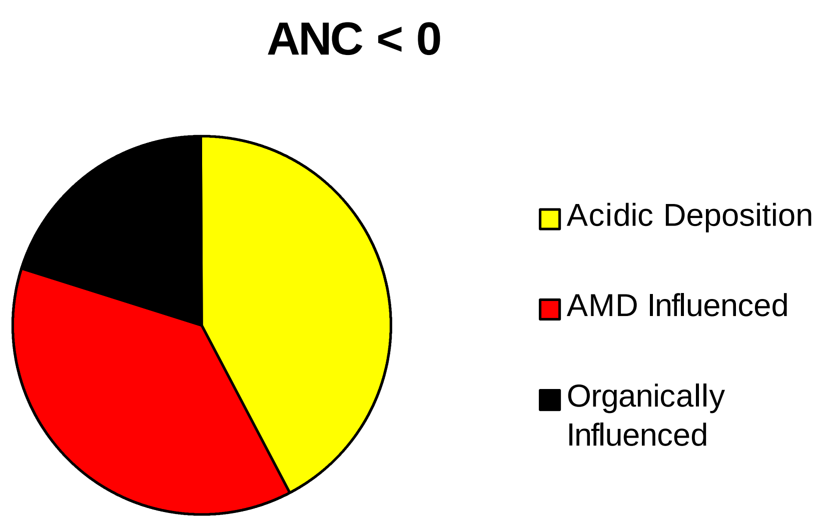


Figure 6-9. Statewide percentage of stream miles with ANC < 200 μeq/l and with ANC < 0 µeq/l by acid source. The category "AMD Influenced" includes sites affected by AMD and by both AMD and acidic deposition. The category "Organically Influenced" includes sites affected by organic sources and by both organic sources and acidic deposition.

6.4 COMPARISON WITH THE 1987 MARYLAND SYNOPTIC STREAM CHEMISTRY SURVEY

MBSS results can be compared with the previous characterization of low ANC in Maryland streams by the 1987 MSSCS (Knapp et al. 1988) (Table 6-1). The MSSCS estimated the percentage of stream miles below certain threshold levels of ANC across the entire State and within each of the State's physiographic regions. MSSCS measurements were taken in 1987, a dry year that received an average of 11% less rainfall than normal (NOAA 1987). The MSSCS estimated that the greatest concentrations of acidic or acid-sensitive streams in the State were in the Southern Coastal Plain (74% of stream miles) and the Appalachian Plateau (53%). There were some important methodological differences between the 1987 MSSCS and the 1995-1997 MBSS. For example, MSSCS sampling was conducted statewide in a single year, while MBSS basins were sampled over a three-year period. Also, the sample frame for the MSSCS specifically excluded streams known to be affected by acid mine drainage, while the MBSS did not exclude these streams. To rectify these differences, the MBSS data were re-stratified by physiographic province, excluding sites that showed AMD as a contributing source of acidity. The results of this analysis are presented in Table 6-2. Because the MSSCS was designed to provide estimates by physiographic province, standard errors are generally lower for the 1987 values. Larger error bounds around MBSS values in Table 6-2 are the result of restratification from basins to physiographic province. In two regions (Ridge and Valley, Blue Ridge), the number of sites sampled by MBSS was lower than in the 1987 survey.

Among the basins sampled in the MBSS, physiographic patterns in ANC are generally consistent with the results of the earlier MSSCS. In the MBSS (Table 6-2), sites in the Appalachian Plateau and Southern Coastal Plain had a high occurrence of acidic or acid-sensitive stream miles, comparable to findings from 1987 for these regions. This result is consistent with the low critical loads estimated for these provinces by Janicki et al., based on watershed hydrology, and the buffering abilities of vegetation, soils and bedrock. Similarly, sites in the Piedmont and the Northern Coastal Plain had a low occurrence of low ANC streams in both MSSCS and MBSS sampling, these regions are thought to have higher critical loads values. The Blue Ridge province showed a significant difference in ANC results between the MSSCS and MBSS sampling, this difference should be interpreted with caution, because the Blue Ridge is a small region and naturally has large statistical variation in results. Similarly, the Valley and Ridge province results for MBSS were noticeably different from those of the MSSCS, with relatively high standard errors (s.e. > 100%). The overall pattern, however, is broad and statistically meaningful. Across all provinces, the MBSS results show a lower percentage of low ANC sites than do the MSSCS results (from 33% to 26%). This suggests a genuine improvement in the condition of Maryland streams from 1987 to 1997.

6.5 ASSOCIATIONS BETWEEN ACIDIFICATION AND BIOLOGICAL CONDITION

Biological data for sites within designated pH and ANC classes were compared to investigate the relationship between acidic conditions (primarily acidic deposition, as explained above) and stream communities. Acidification of streams may cause declines in the biotic integrity of fish assemblages, as a result of the loss of species sensitive to acidification, increases in acid-tolerant species, or the total elimination or reduction in abundance of biota.

Streams sensitive to acidification may experience intermittent periods of low pH which may be harmful to fish populations. In particular, streams may be subject to episodic acidification during springtime, when larval and juvenile fish are particularly vulnerable to adverse changes in water quality. The MBSS study design did not focus on sampling during high stream flow events that could have produced low pH episodes. Instead, the MBSS results corroborate a causal relationship between the potential for episodic acidification and loss of biotic integrity. The MBSS also documented a reduction in abundance and species richness in low ANC streams.

The fish IBI (see Chapter 5) integrates a number of attributes of the fish community, providing a quantitative biological indicator calibrated against reference conditions. A review of IBI scores shows a decline at low pH sites (Figure 6-10) with IBI scores dropping into the poor range at a pH between 5 and 6. Streams sensitive to acidification may experience episodic acidification and even intermittent periods of low pH may be harmful to fish populations. The MBSS results are merely a snapshot of acidity and biological condition at one point in time. The transient nature of episodic acidity and the temporal and spatial heterogeneity of fish populations both contribute to variability and uncertainty in the relationship between pH and fish IBI.

Observed associations between acidity and the fish IBI were paralleled by similar relationships between acidity and other characteristics of the fish community, including species richness and biomass. Among the basins sampled in the 1995-1997 MBSS, fish species richness (mean number of species per stream segment) was significantly lower at sites

Table 6-1.	Percentage of acidic and acid-sensitive stream miles, as estimated by the 1987 Maryland Synoptic Stream Chemistry Survey (MSSCS). Estimates are the percentage of stream miles below threshold ANC values, by physiographic region.

ANC (μeq/l)	PHYSIOGRAPHIC REGION													
	Appalachian Plateau		Valley and Ridge		Blue Ridge		Piedmont		Northern Coastal Plain		Southern Coastal Plain		All	
	n = 139		n = 47		n = 50		n = 125		n = 99		n = 99		n = 559	
	Percent	Std. Error	Percent	Std. Error	Percent	Std. Error	Percent	Std. Erro	Percent	Std. Erro	Percent	Std. Erro	Percent	Std. Error
<0	10.7	3.6	0	0	0	0	0	0	2.1	1.5	7.6	2.9	3.6	0.9
<50	15.7	3.9	0	0	5.8	2.5	0.9	1.0	4.7	2.8	29.3	4.7	10.0	1.4
<200	53.3	4.6	1.5	1.3	26.0	5.7	8.9	3.6	28.3	5.2	74.4	5.0	33.4	2.2

Table 6-2.	Percentage of acidic and acid-sensitive stream miles, as estimated by the 1995-1997 Maryland Biological Stream Survey (MBSS). Estimates are the percentage of stream miles below threshold ANC values, by physiographic region.

ANC (μeq/l)	PHYSIOGRAPHIC REGION													
	Appalachian Plateau		Valley and Ridge		Blue Ridge		Piedmont		Northern Coastal Plain		Southern Coastal Plain		All	
	n = 197		n - 24		n = 11		n = 385		n = 204		n = 138		n = 954	
	Percent	Std. Error	Percent	Std. Error	Percent	Std. Error	Percent	Std. Error	Percent	Std. Error	Percent	Std. Error	Percent	Std. Error
<0	3.4	6.8	0	0	0	0	0	0	0.6	1.3	4.9	6.2	1.4	1.5
<50	6.4	12.3	8.2	14.7	0	0	0	0	2.4	3.3	16.9	8.1	5.0	3.5
<200	53.3	20.3	16.4	19.5	0	0	5.6	4.8	19.2	11.3	63.6	0	25.9	3.4

*Variance statistically undefined

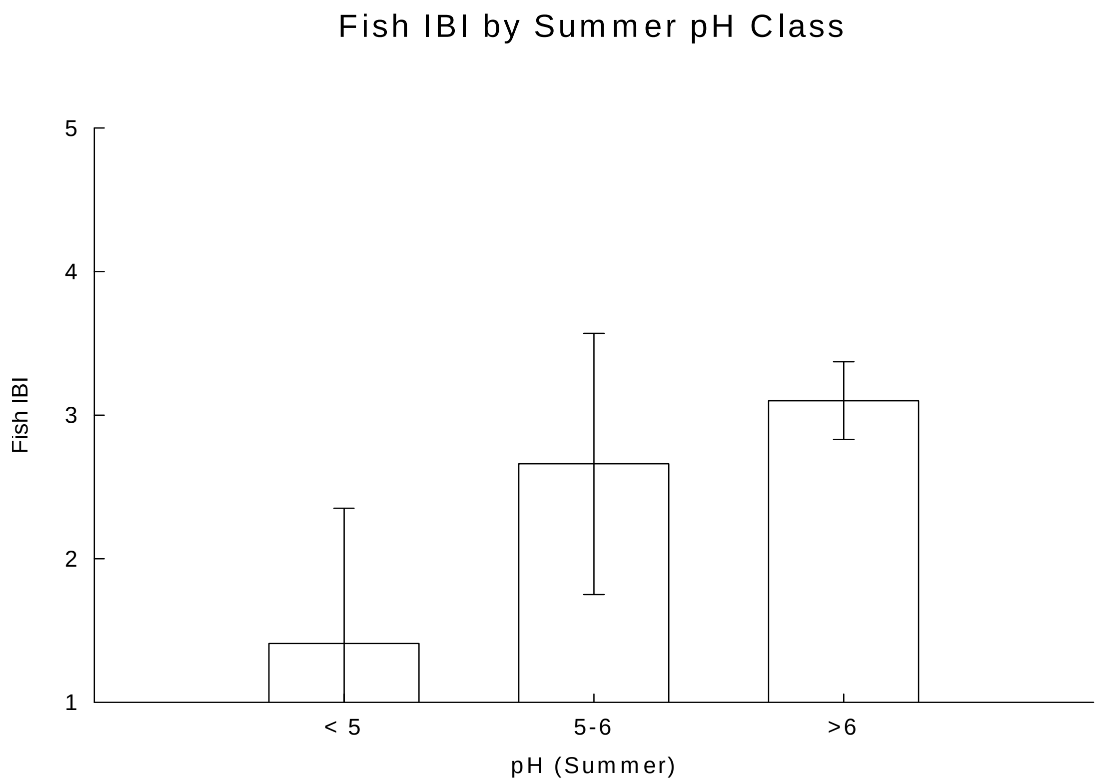


Figure 6-10. Fish IBI by summer pH class (< 5, 5-6, > 6) for the 1995-1997 MBSS

sensitive to acidification (ANC 50-200 μeq/l) than where ANC values were higher (>200 μeq/l) (Figure 6-11). For sites with ANC < 0, fish species richness was severely diminished.

Fish biomass also varied with ANC. Statewide, total fish biomass decreased dramatically in ANC class 50-200, compared to ANC class > 200 (Figure 6-12). Total fish biomass in ANC class 0-50 was less than half than that in ANC class 50-200. Gamefish do not persist where ANC is < 0, therefore their biomass drops to zero in that class.

Other biological communities such as macroinvertebrates and amphibians and reptiles may offer additional clues to help detect the impacts of acidification. Two measures of the benthic macroinvertebrate community, the benthic IBI and the Hilsenhoff Biotic Index (Chapter 5), were compared among ANC classes. The benthic IBI combines several measures of the abundance and diversity of benthic macroinvertebrate organisms. Since benthic communities are sedentary, they tend to experience the integrated effects of chronic and episodic acidification over many seasons. Thus, the benthic IBI may be a valuable indicator of the effects of chronic acidification in Maryland streams. It is not surprising that the benthic IBI decreases strongly with low pH; and passes into the "very poor" rating for pH < 5 (Figure 6-13). Because benthos are relatively immobile, the benthic IBI is intrinsically less uncertain than the fish IBI and is probably a more reliable indicator of the effects of chronic acidification.

A comparison between benthic and fish IBI scores by ANC class reveals similar results (Figure 6-14). Both indices decrease with low ANC and are "very poor" for ANC < 0. It is not clear why IBI scores are higher for ANC 50-200 than for ANC > 200. However, it is important to note that this analysis only considers the effects of acidification on biological condition; many other anthropogenic and natural factors affect IBI scores and may have confounding effects on this analysis.

The Hilsenhoff Biotic Index, which increases with the presence of pollution-tolerant macroinvertebrate species, was highest at sites with 0-50 μeq/l (Hilsenhoff = 5.1). The average value of the index was lowest for sites with ANC < 0 (Hilsenhoff = 3.9). This may be indicate that the Hilsenhoff Biotic Index (originally developed to detect organic pollution) is not well suited to detecting acidification.

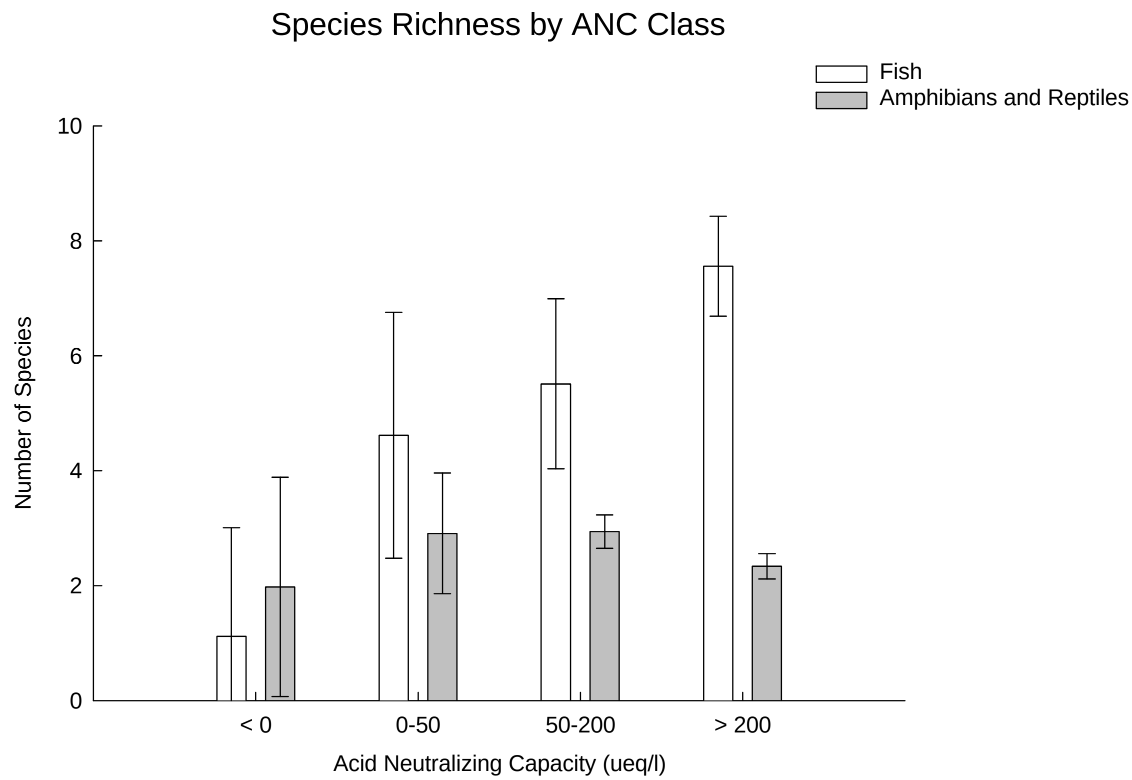


Figure 6-11. Fish and amphibian and reptile species richness by ANC class (< 0, 0-50, 50-200, > 200 μeq/l) for the 1995-1997 MBSS

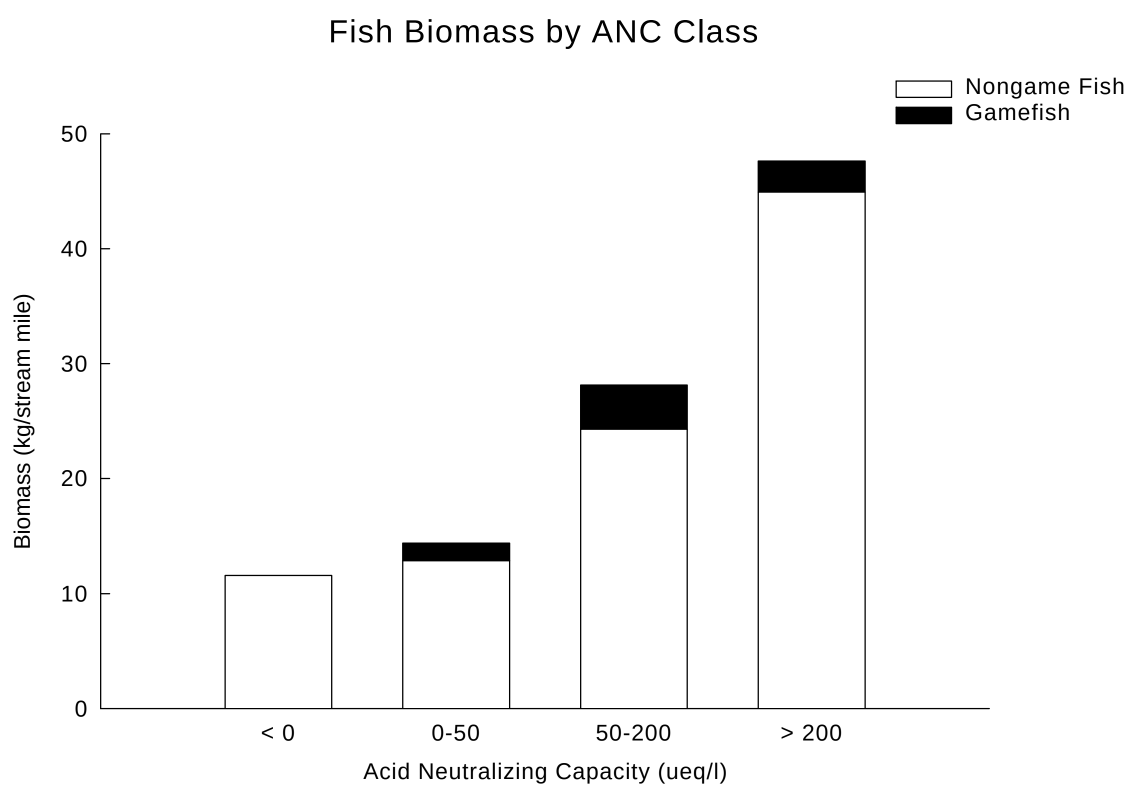


Figure 6-12. Statewide biomass estimates (kg/stream mile) for nongame fish and gamefish by ANC class(< 0, 0-50, 50-200, > 200 μeq/l), 1995-1997 MBSS

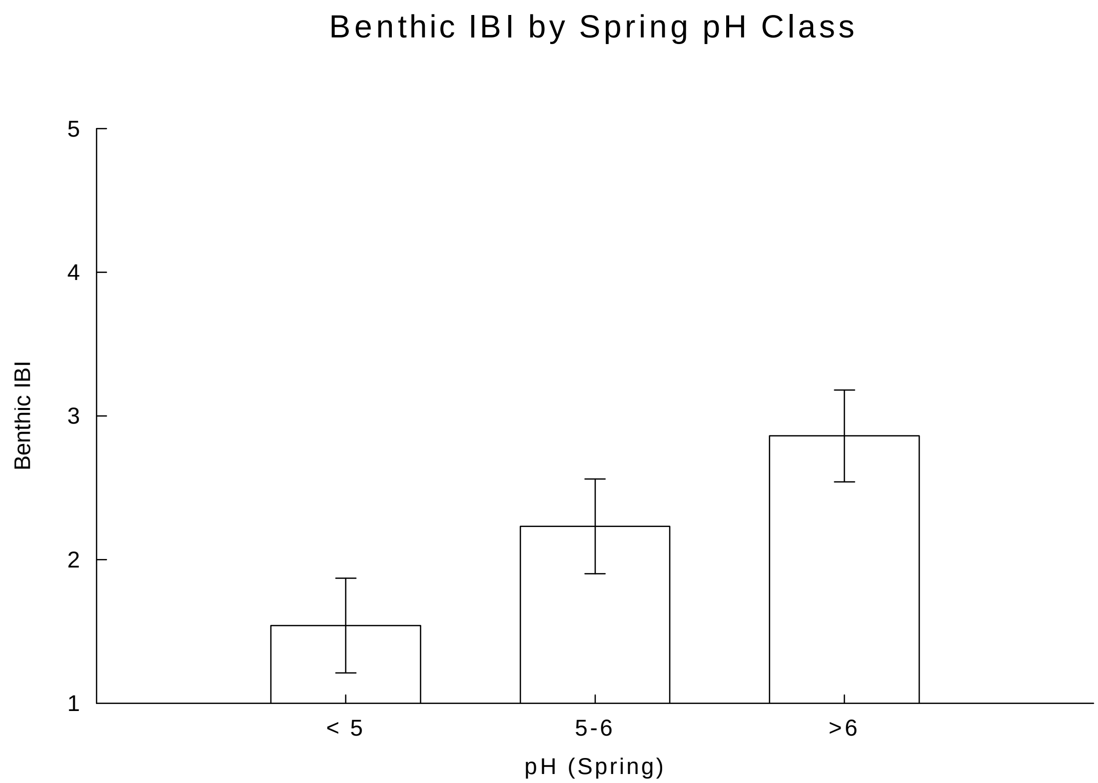


Figure 6-13. Benthic IBI by spring pH class (< 5, 5-6, > 6) for the 1995-1997 MBSS

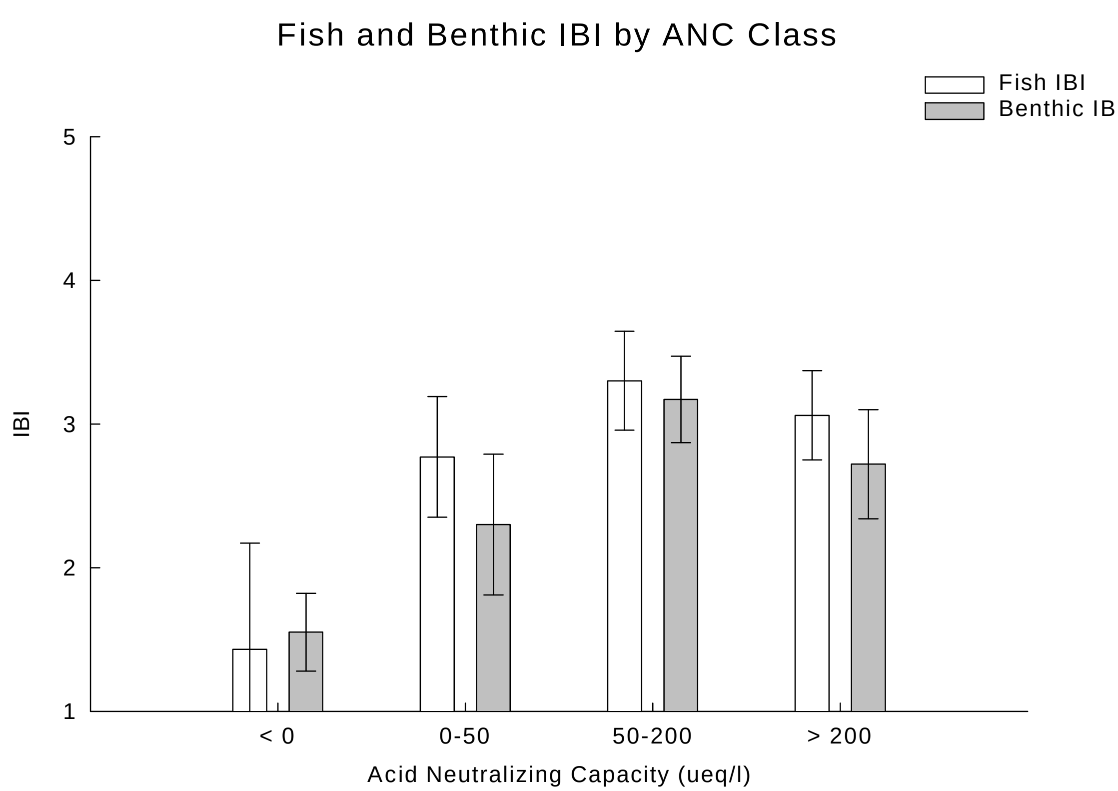


Figure 6-14. Fish and benthic IBI by ANC class (< 0, 0-50, 50-200, > 200 μeq/l) for the 1995-1997 MBSS

Table 6-3. Fish species found at 1995-1997 MBSS sites with summer pH < 6.5				
	pH < 5.0	**pH 5.0 - 5.5**	**pH 5.5 - 6.0**	**pH 6.0 - 6.5**
Least brook lamprey		X	X	X
Sea lamprey			X	X
American eel		X	X	X
Chain pickerel				
Redfin pickerel		X	X	X
	X	X	X	X
Eastern mudminnow				
	X	X	X	X
Blacknose dace				
Bluntnose minnow			X	X
Central stoneroller				X
Common shiner				X
Creek chub				X
Cutlips minnow			X	X
Fallfish			X	X
Golden shiner		X	X	X
Ironcolor shiner			X	X
Longnose dace				X
River chub			X	X
Rosyface shiner				X
Rosyside dace				X
Satinfin shiner		X	X	X
Spotfin shiner				X
Spottail shiner				X
Swallowtail shiner				X
			X	X
Creek chubsucker				
Northern hogsucker		X	X	X
White sucker				X
			X	X
Brown bullhead				
Margined madtom			X	X
Tadpole madtom			X	X
Yellow bullhead		X	X	X
			X	X
Brook trout				
Brown trout			X	X
				X
Pirate perch	X			
			X	X
Banded killifish				
Mosquitofish				X
				X

Table 6-3. Cont'd				
	pH < 5.0	**pH 5.0 - 5.5**	**pH 5.5 - 6.0**	**pH 6.0 - 6.5**
Mottled sculpin			X	X
Potomac sculpin			X	X
Banded sunfish	X	X		X
Black crappie				X
Bluegill		X	X	X
Bluespotted sunfish	X	X	X	X
Flier				X
Green sunfish			X	X
Largemouth bass			X	X
Mud sunfish	X			X
Pumpkinseed		X	X	X
Redbreast sunfish			X	X
Rock bass				X
Smallmouth bass				X
Warmouth		X	X	X
Fantail darter			X	X
Greenside darter				X
Shield darter				X
Swamp darter			X	X
Tessellated darter		X	X	X
Yellow perch				X
Total Number of Species	**6**	**15**	**34**	**56**

Another measure of biological condition available from MBSS data is the species richness of amphibians and reptiles. Species richness was slightly less at ANC < 0 μeq/l, but showed no significant differences for sites with higher ANC values (Figure 6-11). The differences among classes were not large (a difference of about one species) and may be indicative of factors other than water quality (e.g., the condition of the riparian corridor).

6.6 FISH TOLERANCE TO LOW PH CONDITIONS

A breakdown of fish species composition at low pH sites was examined to determine which species were most tolerant of acidic conditions. The results are shown in Table 6-3. Many of these species have been previously reported as tolerant to low pH conditions (Graham 1993, Baker and Christensen 1991), although not all Maryland fish species were covered by these earlier studies. For the most part, these fish species sampled in the 1995-1997 MBSS were present at pH conditions within previously reported ranges of acid tolerance.

6.7 FISH ABUNDANCE UNDER ACIDIFIED OR ACID-SENSITIVE CONDITIONS

The estimated density of fish (mean number of fish per stream mile) varied under acidified and acid-sensitive conditions. Statewide estimates were calculated for the number of individual fish per stream mile within each of four ANC classes (< 0, 0-50, 50-200, > 200 μeq/l). Estimates reported here were not adjusted for capture efficiency. Across all sites, the number of fish per stream mile declined with low ANC. Only 43% of sites sampled in summer with ANC < 0 μeq/l had fish. In contrast, 91% of the summer sites with ANC of 0-50 μeq/l had fish.

To investigate differences in the abundance of individual fish species, the density of fish within each ANC class was calculated (Table 6-4). Five species of fish were found in all four of the ANC classes: redfin pickerel (*Esox americanus*), eastern mudminnow (*Umbra pygmaea*), pirate perch (*Aphredoderus sayanus*), banded sunfish (*Enneacanthus obesus*), and bluespotted sunfish (*Enneacanthus gloriosus*). The mud sunfish (*Acantharchus pomotis*) was found at sites in every ANC class except 0-50.

Dramatic differences were seen in fish species composition and abundance above and below the threshold for acid sensitivity (ANC = 200 μeq/l). Seventeen species found at sites with ANC > 200 were absent from sites with ANC < 200, while only one species found at ANC < 200 was absent at sites with higher ANC. In addition, 44 species decreased in abundance at ANC 50-200 (as compared to ANC > 200). The average loss between these two ANC classes was 135 fish per stream mile. The species exhibiting the greatest declines were blacknose dace (*Rhinichthys atratulus*; 1,377 fish per stream mile), mottled sculpin (*Cottus bairdi*; 435), rosyside dace (*Clinostomus funduloides;* 464), bluntnose minnow (*Pimephales notatus*; 339) and creek chub (*Semotilis atromaculatus*; 418). Interestingly, some of these species are commonly considered tolerant of human impacts in regions where acidification is not prevalent. Twenty-one species were more abundant at ANC 50-200 than at ANC > 200, but the average increase (41 fish per stream mile) was not large enough to offset the observed declines in other species.

Differences were also seen in fish species composition and abundance between the ANC classes of 50-200 and 0-50. Forty-seven species decreased in abundance at ANC 0-50 (as compared to 50-200). The average loss between these two classes was 85 fish. The species exhibiting the greatest declines were least brook lamprey (*Lampetra aepyptera*), eastern mudminnow, and mottled sculpin. Because lampreys spend up to 7 years as larvae in streams, they may be particularly sensitive to acidic episodes.

Between the ANC classes of 0-50 and < 0, 32 species decreased in abundance at ANC < 0. The density of 30 of these species went to zero when the ANC value was < 0, indicating their intolerance to extreme acidification. The two remaining species - pirate perch and bluespotted sunfish - persisted at sites with high levels of acidification. Four species of fish actually increased in abundance in the ANC < 0 category. These fish were the redfin pickerel, eastern mudminnow, banded sunfish, and mud sunfish. This result indicates that these species are acid-tolerant, consistent with reported tolerance levels (Baker and Christensen 1991; Jenkins and Burkland 1993) and may be outcompeted by less tolerant species in streams with higher ANC values.

Given that an estimated 28% of stream miles in the study area (about 2240 miles) had ANC less than 200 μeq/l, the effects of acidification on many fish populations appear to be significant. It is important to note that this analysis considered only acidification, not other natural or anthropogenic effects on fish abundance. In particular, geographic differences may be responsible for some of the differences observed here. For example, brook trout tend to favor the high-gradient streams of Western Maryland, where ANC conditions < 200 are more common. This geographic difference would explain the apparent increase in brook trout abundance in streams with ANC 50-200, compared to streams in other parts of the state that have ANC > 200 but lack suitable habitat for brook trout.

Table 6-4. Mean number of individual fish per stream mile within each acid neutralizing capacity (ANC) class by species, 1995-1997 MBSS

SPECIES	ANC (ueq/l)							
	< 0		0 -50		50-200		> 200	
	Mean	**Std. Error**	**Mean**	**Std. Error**	**Mean**	**Std. Error**	**Mean**	**Std. Error**
American brook lamprey	0.00	0.00	0.00	0.00	0.07	0.08	39.80	87.58
Least brook lamprey	0.00	0.00	10.33	16.01	331.78	311.02	62.21	41.35
Sea lamprey	0.00	0.00	1.02	1.66	10.09	10.16	8.59	6.95
Longnose gar	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00
American eel	0.00	0.00	159.89	264.88	196.57	186.30	181.44	112.35
Gizzard shad	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.04
Chain pickerel	0.00	0.00	13.52	21.48	33.07	33.67	2.36	1.46
Redfin pickerel	1426.31	3142.75	97.43	157.97	99.54	100.76	48.46	32.40
Eastern mudminnow	5563.91	11783.22	921.53	1448.92	1460.11	1437.77	1473.07	1211.74
Blacknose dace	0.00	0.00	674.66	1154.61	882.63	853.80	2259.67	1415.02
Bluntnose minnow	0.00	0.00	0.00	0.00	20.53	32.53	359.15	222.13
Central stoneroller	0.00	0.00	0.00	0.00	9.28	9.70	230.88	145.65
Comely shiner	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.60
Common carp	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.63
Common shiner	0.00	0.00	0.00	0.00	9.57	10.11	159.33	130.44
Creek chub	0.00	0.00	138.73	222.80	328.31	333.04	745.86	469.55
Cutlips minnow	0.00	0.00	0.00	0.00	17.94		117.34	72.19
Eastern silvery minnow	0.00	0.00	0.00	0.00	0.17	0.19	5.81	4.08
Fallfish	0.00	0.00	24.86	39.19	82.63	77.08	75.97	*
Fathead minnow	0.00	0.00	0.00	0.00	1.83	2.93	104.70	137.44
Golden shiner	0.00	0.00	102.28	177.72	81.46	83.63	65.88	43.83
Goldfish	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.11
Ironcolor shiner	0.00	0.00	0.00	0.00	1.55	1.49	0.17	0.24
Longnose dace	0.00	0.00	1.25	2.36	88.76	88.39	390.16	246.72
Pearl dace	0.00	0.00	821.26	1465.65	0.00	0.00	68.57	62.32
River chub	0.00	0.00	34.21	86.85	3.36	3.44	51.89	*
Rosyface shiner	0.00	0.00	0.00	0.00	0.00	0.00	4.21	2.75
Rosyside dace	0.00	0.00	69.64	107.39	127.82	119.43	591.47	383.16
Satinfin shiner	0.00	0.00	0.00	0.00	2.63	2.94	47.02	33.91
Silverjaw minnow	0.00	0.00	0.00	0.00	0.00	0.00	14.14	9.43
Spotfin shiner	0.00	0.00	0.00	0.00	0.00	0.00	11.84	8.23
Spottail shiner	0.00	0.00	0.00	0.00	16.55	16.33	117.30	428.03
Striped shiner	0.00	0.00	0.00	0.00	3.70	6.09	1.40	2.34
Swallowtail shiner	0.00	0.00	0.00	0.00	11.39	14.45	207.01	193.80
Creek chubsucker	0.00	0.00	30.49	47.65	142.03	136.79	94.77	64.96
Golden redhorse	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Northern hogsucker	0.00	0.00	0.00	0.00	3.41	4.51	44.23	27.66
Shorthead redhorse	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.06
White sucker	0.00	0.00	25.83	41.03	106.39	100.34	416.13	264.01
Brown bullhead	0.00	0.00	2.65	4.32	188.33	276.05	50.06	32.04
Channel catfish	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
Margined madtom	0.00	0.00	10.22	16.86	59.01		85.16	53.09

Table 6-4. Cont'd

SPECIES	ANC (ueq/l)							
	< 0		0 -50		50-200		> 200	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
Tadpole madtom	0.00	0.00	1.54	2.43	80.73	98.04	43.34	33.43
White catfish	0.00	0.00	0.00	0.00	0.06	0.08	0.03	0.02
Yellow bullhead	0.00	0.00	9.29	19.84	3.74	4.59	23.61	14.98
Brook trout	0.00	0.00	73.29	153.72	128.64	129.37	26.71	19.54
Brown trout	0.00	0.00	0.00	0.00	6.88	7.55	36.79	24.65
Cutthroat trout	0.00	0.00	0.00	0.00	0.18	0.17	0.02	0.04
Rainbow trout	0.00	0.00	1.50	3.14	0.89	0.89	1.33	0.93
Pirate perch	58.22	130.62	72.46	114.46	198.27	198.78	145.90	211.77
Banded killifish	0.00	0.00	0.00	0.00	0.38	0.39	23.69	17.62
Mummichog	0.00	0.00	0.00	0.00	0.00	0.00	62.58	53.78
Mosquitofish	0.00	0.00	0.00	0.00	0.49	0.50	6.17	5.40
Checkered sculpin	0.00	0.00	310.01	553.25	0.00	0.00	88.36	166.50
Mottled sculpin	0.00	0.00	51.76	106.24	1046.59	1101.35	1481.42	1030.66
Potomac sculpin	0.00	0.00	0.00	0.00	137.66	146.59	279.25	173.26
Striped bass	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.91
White perch	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.07
Banded sunfish	396.20	878.11	17.84	31.49	4.93	5.54	2.87	2.55
Black crappie	0.00	0.00	0.00	0.00	9.93	10.12	1.33	1.00
Bluegill	0.00	0.00	17.83	28.65	160.98	155.83	170.36	106.22
Bluespotted sunfish	14.55	32.14	171.38	268.46	43.81	50.72	57.68	39.15
Flier	0.00	0.00	0.00	0.00	0.95	0.95	0.00	0.00
Green sunfish	0.00	0.00	0.79	1.29	1.76	1.78	113.06	80.96
Largemouth bass	0.00	0.00	0.26	0.42	10.50	10.25	62.49	55.66
Longear sunfish	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.04
Mud sunfish	6.47	14.51	0.00	0.00	0.46	0.49	0.44	0.34
Pumpkinseed	0.00	0.00	27.37	44.91	71.01	68.37	86.66	54.67
Redbreast sunfish	0.00	0.00	4.65	9.92	48.63	45.67	93.52	58.44
Rock bass	0.00	0.00	0.25	0.56	11.62	12.78	10.13	6.79
Smallmouth bass	0.00	0.00	3.01	6.54	1.09	1.16	7.61	4.83
Warmouth	0.00	0.00	3.24	5.19	11.14	10.53	0.06	0.05
Fantail darter	0.00	0.00	0.00	0.00	38.93	37.15	168.30	106.15
Glassy darter	0.00	0.00	0.00	0.00	2.05	2.10	0.43	0.38
Greenside darter	0.00	0.00	0.00	0.00	2.13	2.36	22.71	*
Johnny darter	0.00	0.00	0.00	0.00	47.57	61.61	2.03	3.33
Logperch	0.00	0.00	0.00	0.00	0.00	0.00	1.81	1.84
Rainbow darter	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02
Shield darter	0.00	0.00	0.00	0.00	1.52	2.59	16.14	20.54
Stripeback darter	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.10
Swamp darter	0.00	0.00	4.23	7.34	0.21	0.22	1.58	1.26
Tessellated darter	0.00	0.00	64.58	102.81	204.47	197.40	514.91	414.64
Yellow perch	0.00	0.00	7.93	13.99	24.91	41.50	2.64	1.85
Total Number of Species	**6**		**38**		**64**		**81**	

7 PHYSICAL HABITAT

The Maryland Biological Stream Survey (MBSS or the Survey) collects a variety of data to characterize physical habitat and to assess relationships between physical habitat and biota. Observations and measurements include a semi-quantitative assessment of several key habitat parameters, presence/absence of habitat features, measures of stream size and channel geometry, presence and type of riparian vegetation, and assessments of bank stability. With these data, a multimetric index of physical habitat integrity was recently developed for the Survey (Hall et al. 1999b). This chapter synthesizes the results of physical habitat characterization, using both individual measures and the Physical Habitat Index, and explores associations between physical habitat parameters and biological communities.

7.1 BACKGROUND

Stream health, as determined by the condition of biological communities, has been shown to be directly correlated to physical habitat quality (Rankin 1995, Richards et al. 1993, Roth et al. 1996). Previous MBSS reports have described geographic patterns in the physical habitat of Maryland streams and have correlated physical habitat quality with biological resources (Roth et al. 1997, 1998). In this report, we expand on earlier analyses and examine the relationships between physical habitat and stream biota statewide.

Although programs to improve the quality of streams and rivers tend to focus on water chemistry-based definitions of stream quality, physical habitat degradation can have an equal or greater effect on stream ecosystems and their biological communities. Habitat loss and degradation has been identified as one of six critical factors affecting biological diversity in streams worldwide; habitat alteration is cited as a leading cause of fish species extinctions, contributing to 73% of extinctions in North America during this century (Allan and Flecker 1993, Miller et al. 1989). Habitat degradation can result from a variety of human impacts occurring within the stream itself and in the surrounding watershed. Typical instream impacts include sedimentation, impoundment, and stream channelization. Urban development, timber harvesting, agriculture, livestock grazing, and the draining or filling of wetlands are well-known examples of human activities affecting streams at a broader scale.

Alone or in combination, these human activities may cause changes in vegetative cover, sediment loads, hydrology, and other factors influencing stream habitat quality. The amount of vegetative cover in a watershed regulates the flow of water, nutrients, and sediments to adjacent streams. In watersheds impacted by anthropogenic stress, riparian (streamside) forests can ameliorate inputs of nutrients, sediments, and other pollutants to streams. They also provide local benefits of shade, overhead cover, leaf litter to feed the aquatic food web, and large woody debris, which in turn provides cover and forms pool and riffle microhabitats (Karr and Schlosser 1978, Gregory et al. 1991). Removal of riparian vegetation can increase stream temperatures, often with adverse effects on stream fish (Barton et al. 1985). The loss of watershed or riparian vegetation increases the potential for overland and channel erosion, often increasing the siltation of stream bottoms and obliterating the clean gravel surfaces used by many fish species as spawning habitat (Berkman and Rabeni 1987). Stream bottoms that become embedded with increased sediment loads provide less habitat for many benthic macroinvertebrates. Stream channelization alters runoff patterns and creates "flashy" streams with more extreme high and low flows, increased scouring, and streambank erosion. These altered flows accelerate downcutting and widening of stream channels. This increased hydrologic variability is exacerbated by urbanization, which increases the amount of impervious surface in a watershed and causes higher overland flows to streams, especially during storm events. Streams with highly altered flow regimes often become wide, shallow, and homogeneous, resulting in poor habitat for many fish species (Schlosser 1991). Concrete-lined streams are perhaps the most severe example of habitat loss for fish, benthic macroinvertebrates, and other aquatic animals.

The Survey collects physical habitat data for streams throughout the State, following methods largely adapted from other national and regional protocols (Plafkin et al. 1989, Barbour and Stribling 1991, Ohio EPA 1987, Rankin 1989; see Chapter 2 for details). It provides estimates, on a basinwide and statewide scale, of the extent and types of stream habitat degradation occurring in Maryland streams. In addition, the recently-developed Physical Habitat Index (PHI) can be used to assess the extent of stream habitat in various conditions. Analyses using the data from the 1995-1997 MBSS were conducted to identify key physical habitat parameters that may affect fish and benthic macroinvertebrate communities. Associations between the PHI and biological communities are also presented below.

7.2 EVALUATION OF PHYSICAL HABITAT DEGRADATION USING INDIVIDUAL PARAMETERS

A key question of interest to stream managers is: To what extent are Maryland streams affected by various types of physical habitat degradation? For example, what percentage of stream miles have low instream habitat quality, poor riparian buffers, or other evidence of degradation? Current MBSS results provide statewide estimates from data collected between 1995 and 1997. Statewide physical habitat assessment results (percentage of stream miles in each class for a series of factors) are presented in Appendix D (Table D-1); highlights for the following parameters are presented below: riparian vegetation, stream alteration, bank erosion potential, instream condition, aesthetic quality and remoteness, and quantity of available physical habitat.

7.2.1 Riparian Vegetation

A complete characterization of stream habitat goes beyond in-channel measures and includes the riparian zone adjacent to the stream. The effectiveness of the riparian buffer in mitigating nutrient loading and providing other benefits to the stream (described above) varies with the type and amount of riparian vegetation. MBSS results describe both the type and extent of local riparian vegetation, estimated as the functional width of the riparian buffer along each 75-m sample segment. Statewide, an estimated 58% of stream miles had forested buffers, 14% had other kinds of vegetated buffers (wetland, old field, tall grass, or lawn), and 28%, while perhaps having some vegetation, had an effective buffer width of 0 m (this estimate was based on sites where no buffer was present or where an outfall pipe was observed, draining directly into the stream segment). An estimated 40% of stream miles had at least a 50-m riparian buffer (Figure 7-1); about 32% had buffer vegetation less than 50 m wide. The data indicate that as buffer width increases, buffer type switches from roughly an even split between forest and other vegetation to nearly entirely forested buffer.

A statewide map (Figure 7-2) shows the distribution of riparian buffer widths observed at MBSS sites. Sites with at least a 50-m vegetated buffer were distributed throughout the state. The largest concentrations of sites with no buffer or buffer widths of less than 50-m were in the agricultural Middle Potomac basin and portions of the Baltimore-Washington corridor; other sites with less than a 50-m buffer were scattered throughout the state.

Estimates of the extent of stream miles lacking riparian buffer indicated that 28% of stream miles statewide had no buffer, while another 7% had only a vegetated buffer 1-5 m wide. The Patapsco basin had the largest percentage of poorly buffered stream miles, with 54% lacking any buffer and 11% with 1-5 m of vegetation (in 1996 sampling). Forty-seven percent of stream miles in the Middle Potomac basin were unbuffered, while another 8% had 1-5 m of vegetation. In other basins, 0 to 37% of stream miles had no riparian buffer, and 1 to 32% had only 1-5 m buffers (Figure 7-3). The problem of insufficient riparian buffer is clearly widespread throughout the State, presenting numerous opportunities for stream restoration through re-establishment of trees and other vegetation along riparian corridors. Riparian restoration efforts should be targeted to areas with the greatest potential for ecological benefit (e.g., reduced nutrient runoff, enhanced stream habitat and water quality).

7.2.2 Stream Alteration

Channelization, beaver dams, and artificial stream blockages can also affect the quality and availability of stream habitat. Beaver dams can flood large areas, dramatically changing stream character. Dams alter upstream areas by converting lotic stream habitat to lentic (ponded) habitat, resulting in silt deposition and increased water temperature in summer. In addition, dams, culverts, and other man-made structures pose a barrier to the movement of fish.

Over the three-year study, 57 sites were noted for having beaver ponds or being unsampleable because of beaver activity. Both types of records were used to estimate the percentage of stream miles with beaver ponds. Statewide, an estimated 4% of stream miles had beaver ponds. The areas with the greatest extent of beaver ponds were the Lower Potomac (16% of stream miles), Choptank (12% in 1997 sampling), and Chester (11%) basins (Figure 7-4).

Artificial blockages were encountered at 18 sites over the three-year study. Eight sites had dams, 1 to 3 meters high. Four dams were located in the Patapsco basin, three were located in the Gunpowder basin, and one was located in the Elk. Culverts were reported at nine sites, each creating a blockage about 1 meter high. Two were found in the Patuxent basin, and one each was found in the Patapsco, Pocomoke, Middle Potomac, Lower Potomac, Chester, and Bush basins. A less than one-meter-high gaging station weir was also reported blocking the stream at one site in the Patapsco basin.

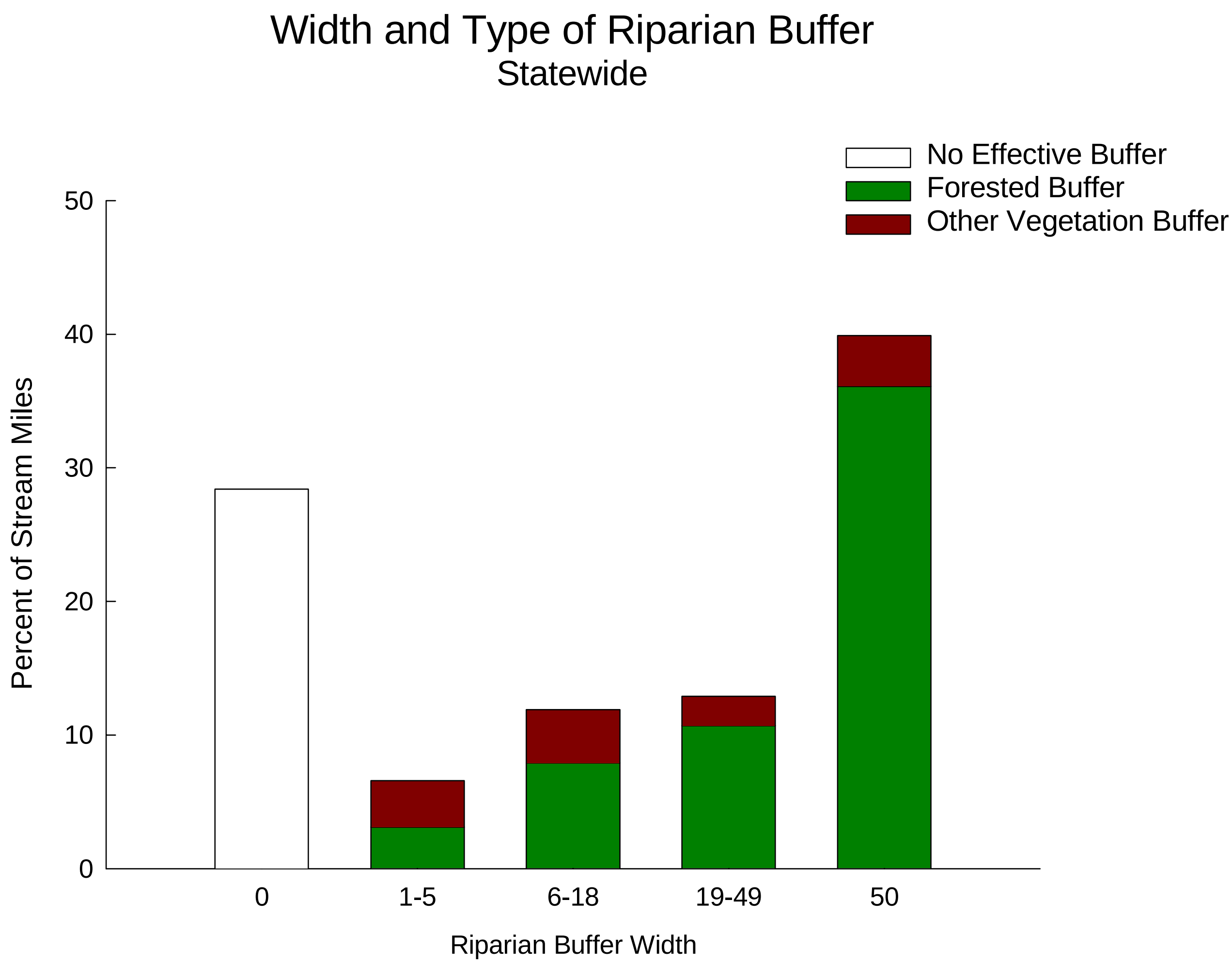


Figure 7-1. Percentage of stream miles by riparian buffer type and width for the 1995-1997 MBSS. The category "Other Vegetation Buffer" includes old field, emergent vegetation, mowed lawn, tall grass, and wetland vegetation. No effective buffer indicates that although some vegetation may be present, runoff (such as from an outfall pipe) occurs directly into the stream.

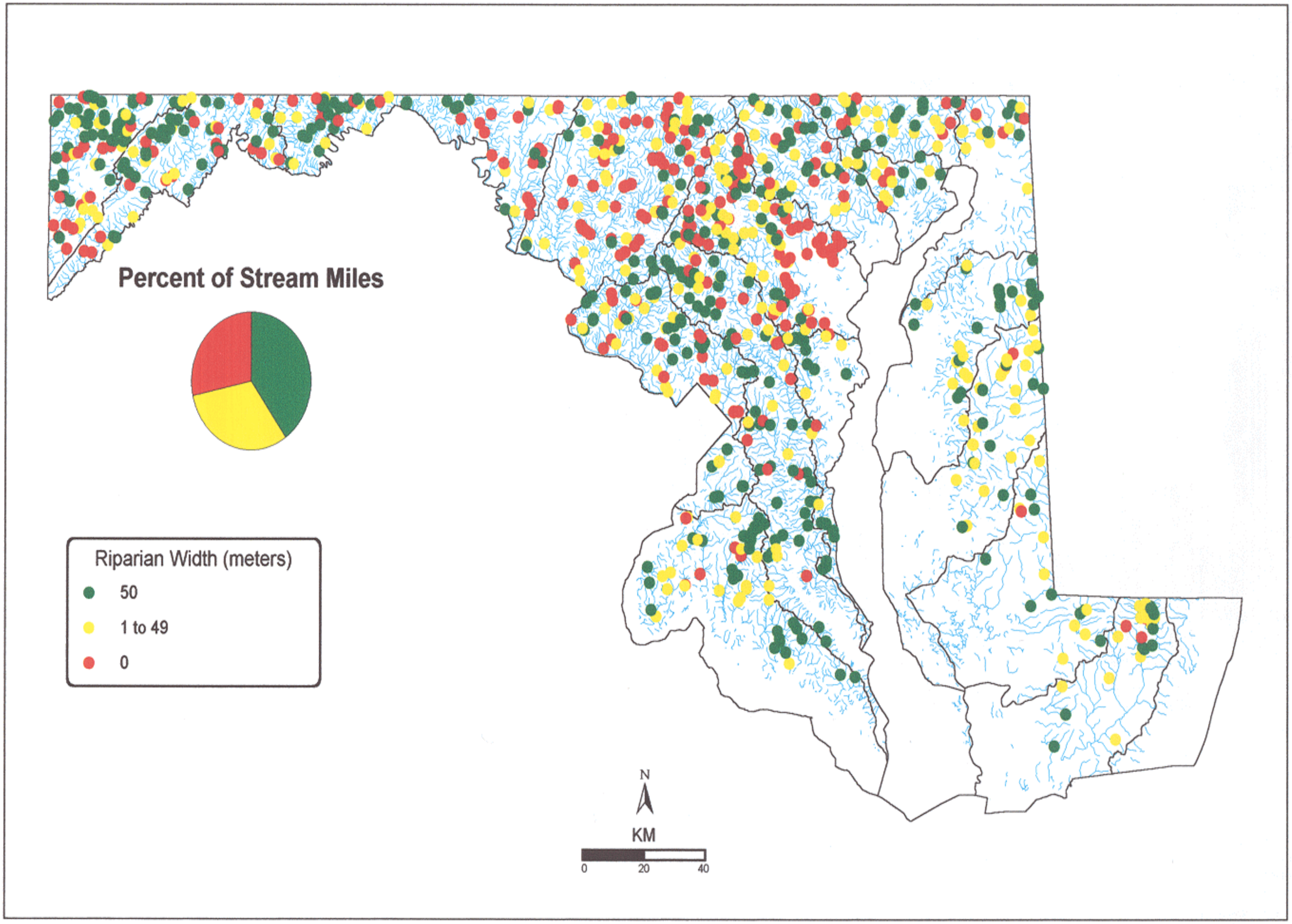


Figure 7-2. Riparian buffer width at sites sampled in the 1995-1997 MBSS. Pie chart indicates the statewide percentage of stream miles in each riparian width category.

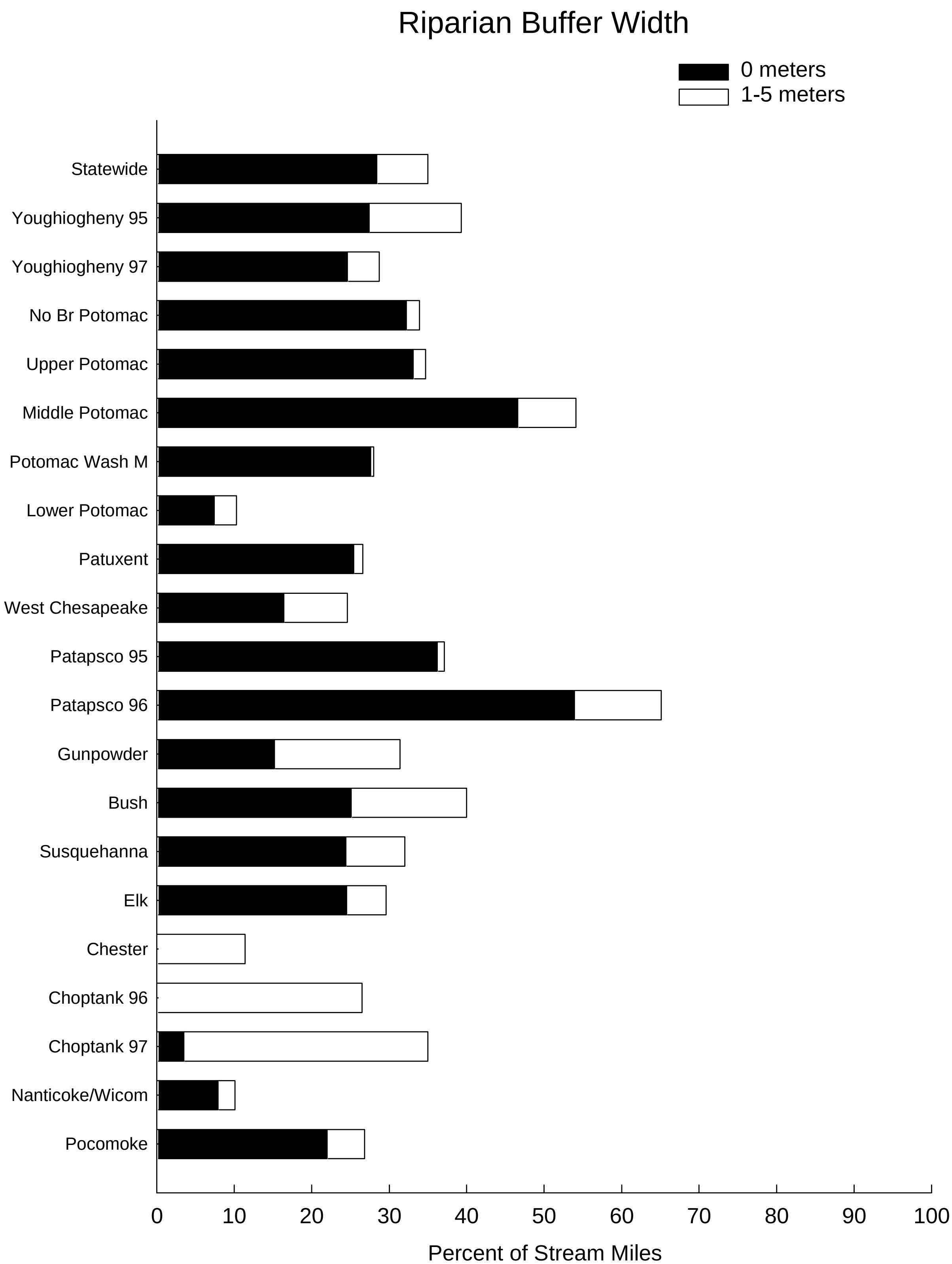


Figure 7-3. Percentage of stream miles with riparian buffer width less than 5 meters, statewide and for the basins sampled in the 1995-1997 MBSS

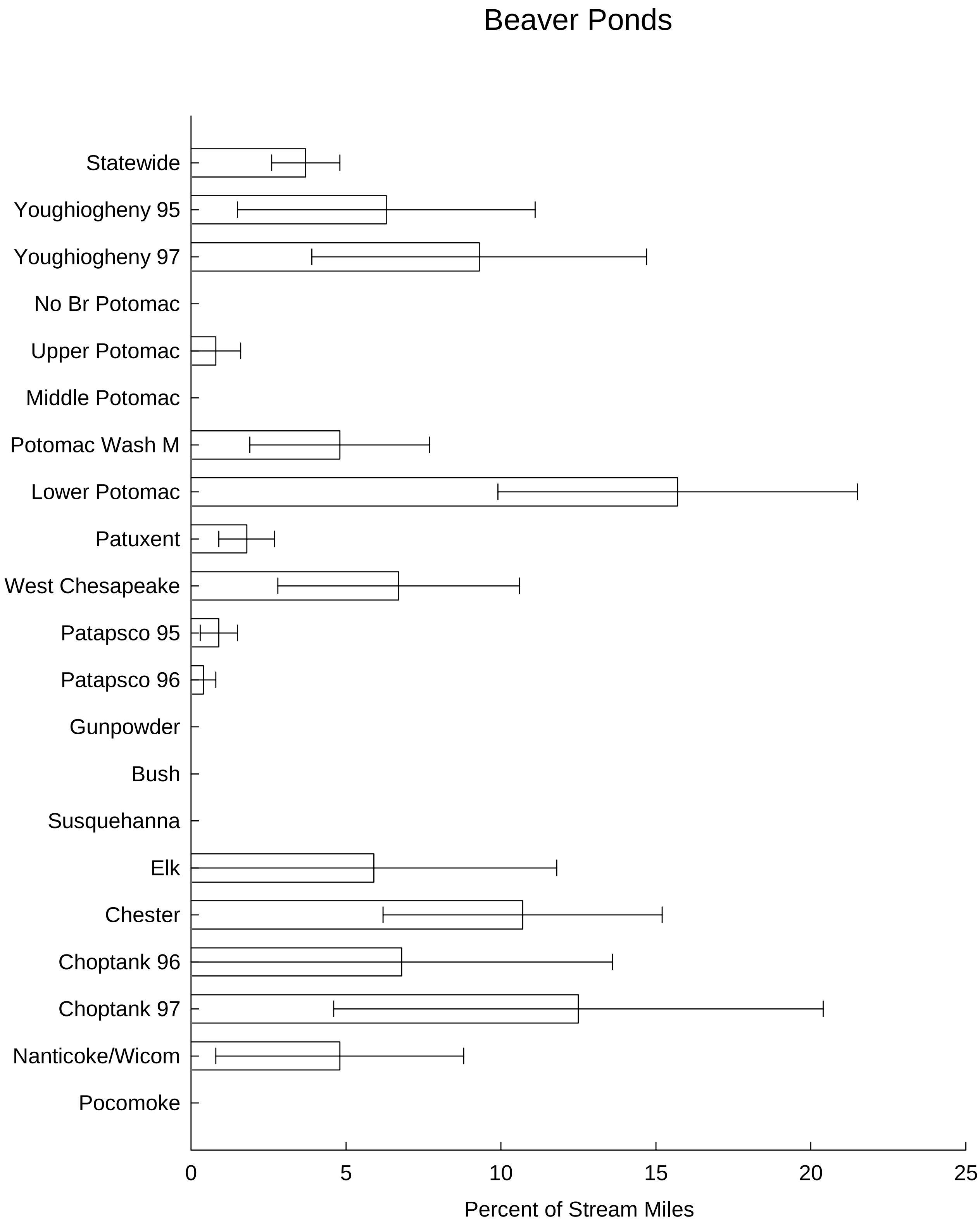


Figure 7-4. Percentage of stream miles with beaver ponds, statewide and for the basins sampled in the 1995-1997 MBSS

Channelization can also substantially alter the character of the stream. Historically, streams were commonly channelized to drain fields and to provide flood control. Today, streams in urban areas are often channelized to accommodate road-building or to drain stormwater from developed areas. When previously meandering streams are straightened, they lose their natural connection to the floodplain, with significant adverse consequences for the stream ecosystem. For example, increased flows during storm events can lead to greater scouring, greater bank instability, and disruption of the natural pattern of riffle and pool habitats. At other times, decreased baseflows can result in stagnant ditches with substrates degraded by heavy sediment deposition. MBSS results indicate that stream channelization is widespread in Maryland. Statewide, an estimated 17% of stream miles are channelized. The greatest extent of channelization was observed in the Pocomoke (81% of stream miles), Nanticoke/Wicomico (52%), Chester (44%), Patapsco (38% in 1996 sampling) and Choptank (38% in 1997 sampling) basins (Figure 7-5).

7.2.3 Bank Erosion Potential

Field assessments of several factors related to bank erosion potential were made at each site sampled in the 1995-1997 MBSS. Using a standard set of criteria to categorize observations (Rosgen 1996), field crews collected data on five stream bank erodibility factors, as follows:

- Bank height to bankfull height (the ratio of streambank height to bankfull stage);
- Bank angle (the slope of the streambank);
- Bank root coverage (the amount of bank surface protection given by roots and other woody debris, rooting density, and ratio of riparian vegetation rooting depth to streambank height);
- Soil stratification (bank material stratigraphy and presence of soil lenses); and
- Particle size (the composition of streambank materials).

Each of these five individual factors was assigned a rating based on criteria and diagrams from Rosgen (1996). The original classification system of low, moderate, and high bank erosion potential was changed to a five-point scale to allow for intermediate ratings (low-to-moderate, moderate-to-high). For each factor, a rating of 1 was most favorable (i.e., with the least potential for bank erosion and greater bank stability). A 5 was least favorable (i.e., with the highest potential for bank erosion and the least stable bank conditions). A rating of 3 indicated moderate bank erosion potential and fair bank stability conditions.

To obtain an overall erosion potential score for each site, the scores for bank height to bankfull height, bank angle, and bank root coverage were summed together, giving a possible range of 3 to 15. Statewide and basin-specific estimates of the percentage of stream miles in each of the following categories were calculated:

- Lowest potential for erosion: $3 \leq$ Erodibility index ≤ 6
- Low potential for erosion: $6 <$ Erodibility index ≤ 9
- High potential for erosion: $9 <$ Erodibility index ≤ 12
- Highest potential for erosion: $12 <$ Erodibility index ≤ 15

Statewide, 35% of stream miles had high potential and 7% of stream miles had highest potential for erosion, according to this index. Another 35% had low potential and 22% had lowest potential for erosion. Basins with the most extensive erosion potential included the Patuxent (total of 87% of stream miles with high or highest potential for erosion), Elk (69%), Bush (64%), Pocomoke (59%), and Patapsco (58% in 1996 sampling) (Figure 7-6). The Pocomoke basin had the greatest percentage of stream miles in the highest erosion potential category (35%).

7.2.4 Instream Condition

A number of parameters describing the habitat condition within the stream channel were qualitatively assessed at each sample site. Ratings of 0-20 were assigned to each of five parameters: instream habitat structure, epifaunal substrate, velocity/depth diversity, pool/glide/eddy quality, and riffle/run quality. Scores for each of these parameters were grouped by the four scoring categories used in field observations: poor (1-5 points), marginal (6-10), sub-optimal (11-15), and optimal (16-20). For each parameter, the percentage of stream miles in each basin with low-scoring (poor to marginal) habitat is shown in Figures 7-7 to 7-11. Low scores are generally indicative of conditions less able to support biological communities; such scores represent areas of degradation. An accurate determination of whether a score represents degradation by human activities depends on what score is expected under natural conditions (as found in minimally impacted reference streams). Reference conditions vary geographically; for example, a riffle/run quality score for an unimpacted, stream

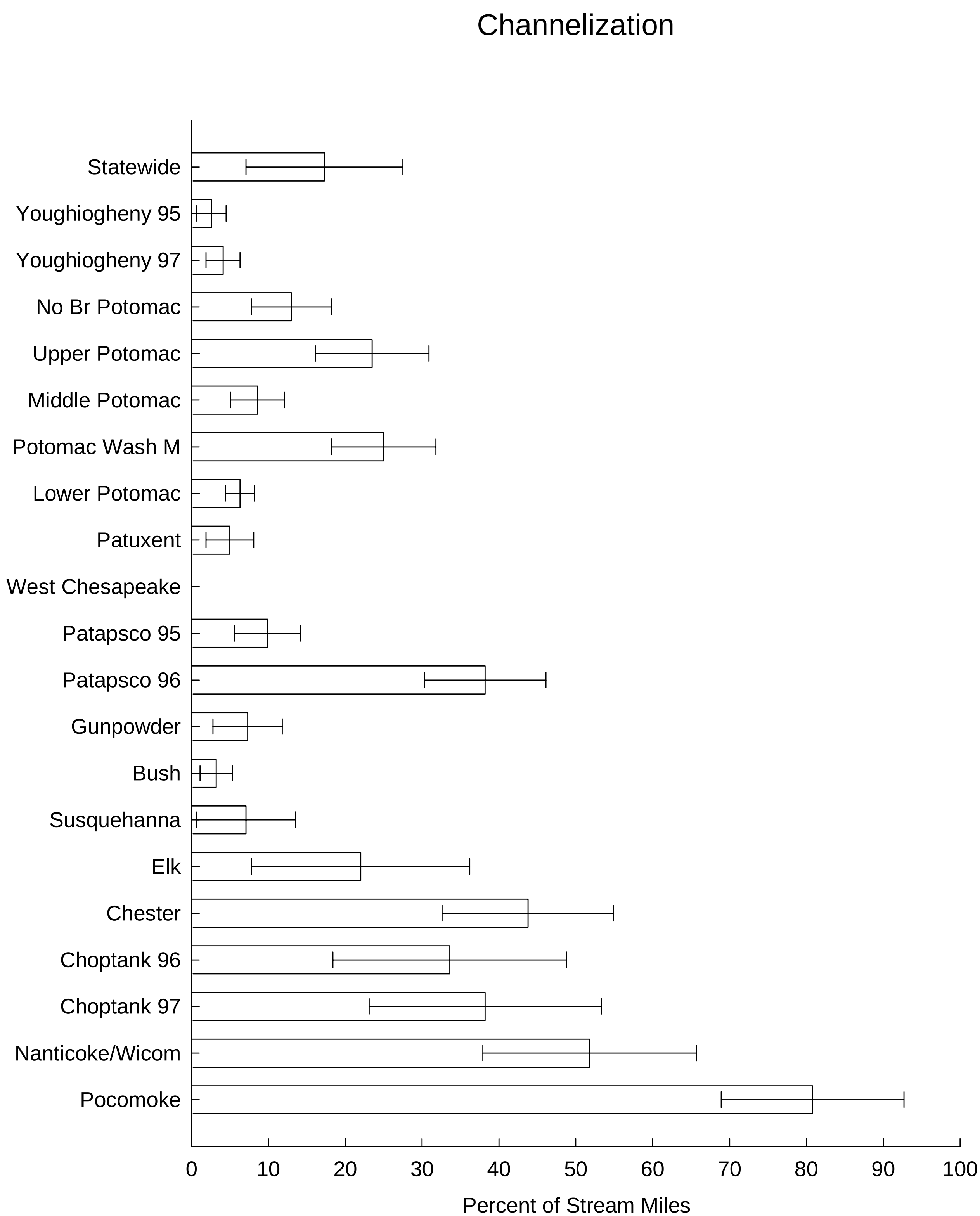


Figure 7-5. Percentage of stream miles with evidence of channelization, statewide and for the basins sampled in the 1995-1997 MBSS

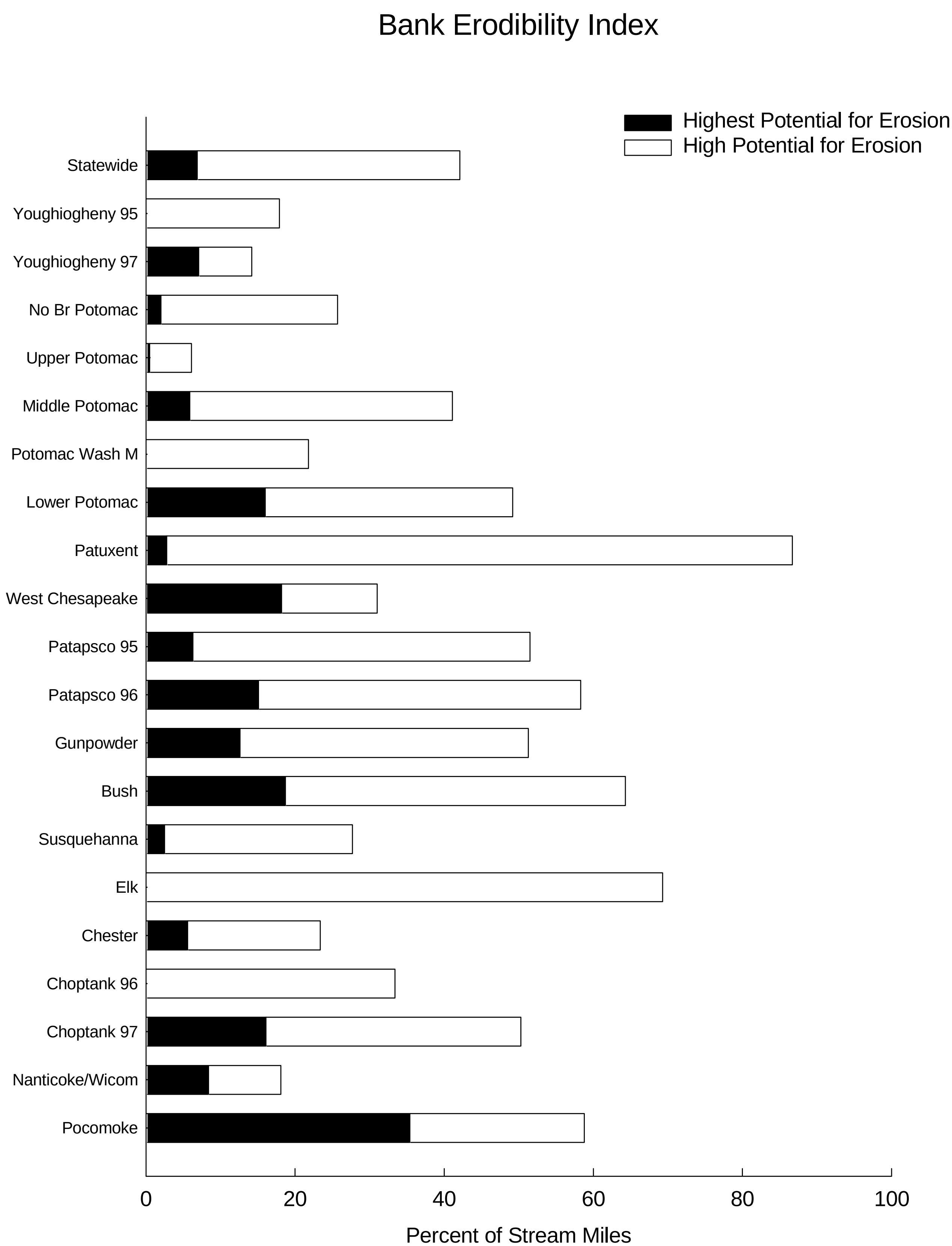


Figure 7-6. Percentage of stream miles in "Highest" and "High" categories of the bank erodibility index, statewide and for the basins sampled in the 1995-1997 MBSS

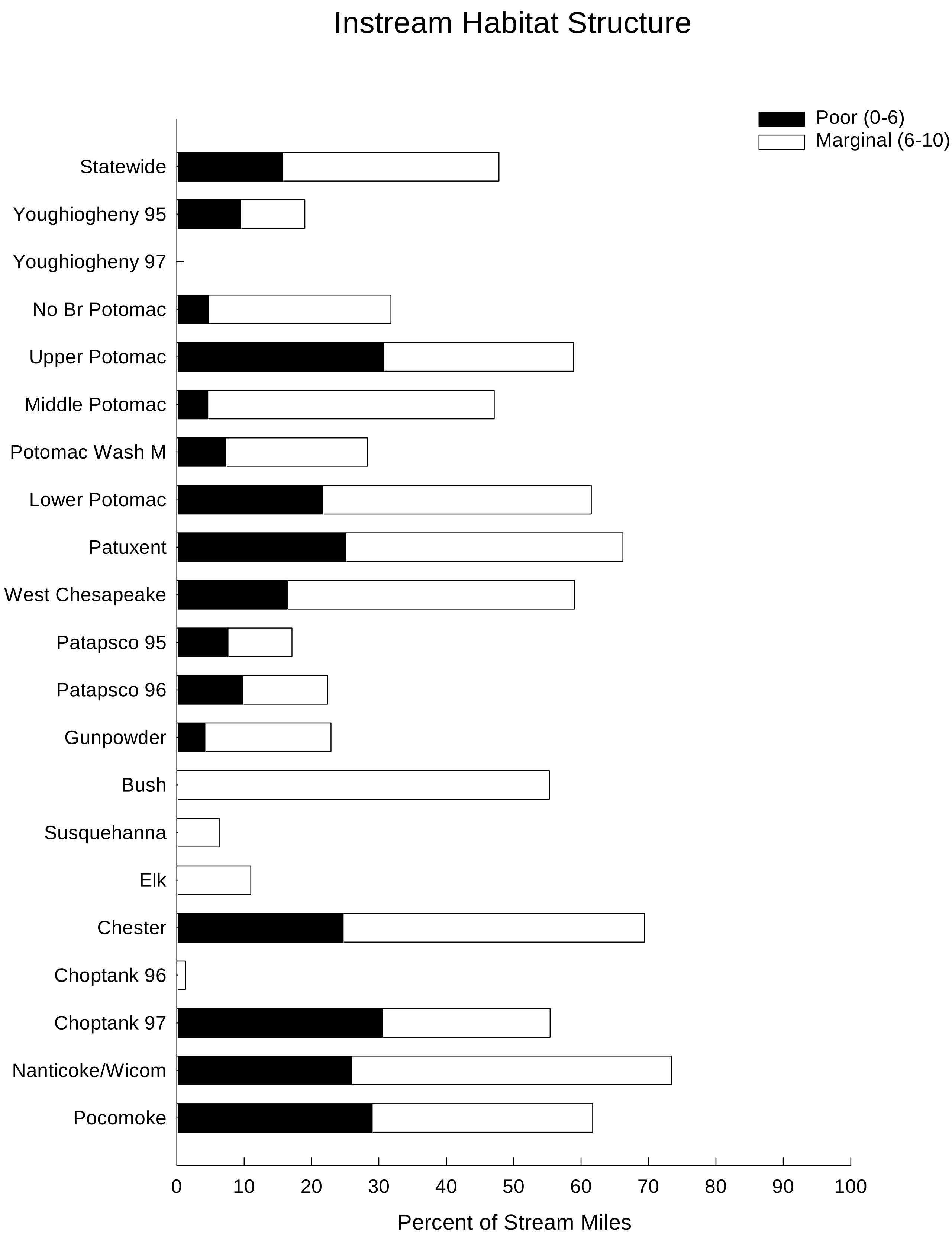


Figure 7-7. Percentage of stream miles with poor and marginal instream habitat structure, statewide and for the basins sampled in the 1995-1997 MBSS

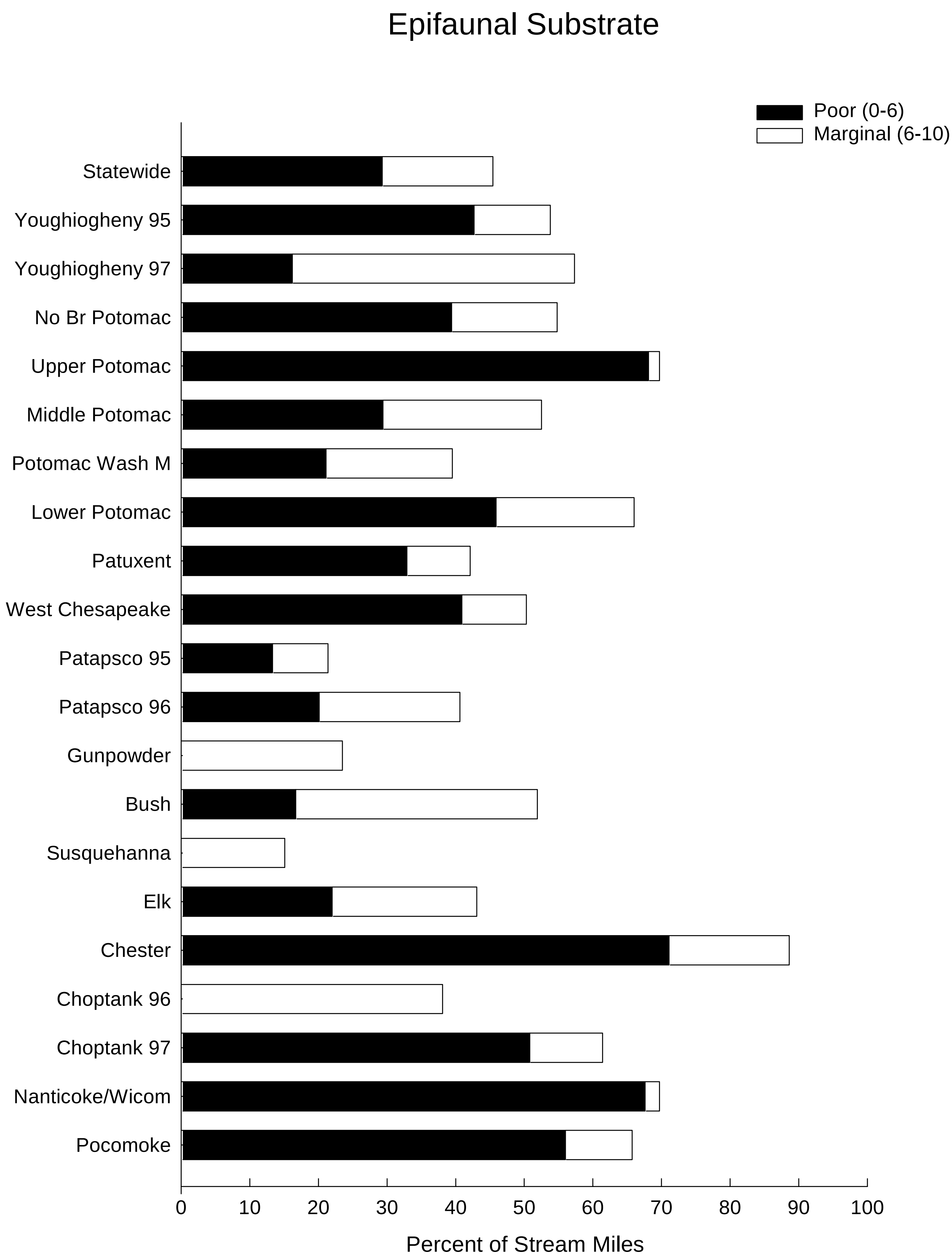


Figure 7-8. Percentage of stream miles with poor and marginal epifaunal substrate, statewide and for the basins sampled in he 1995-1997 MBSS

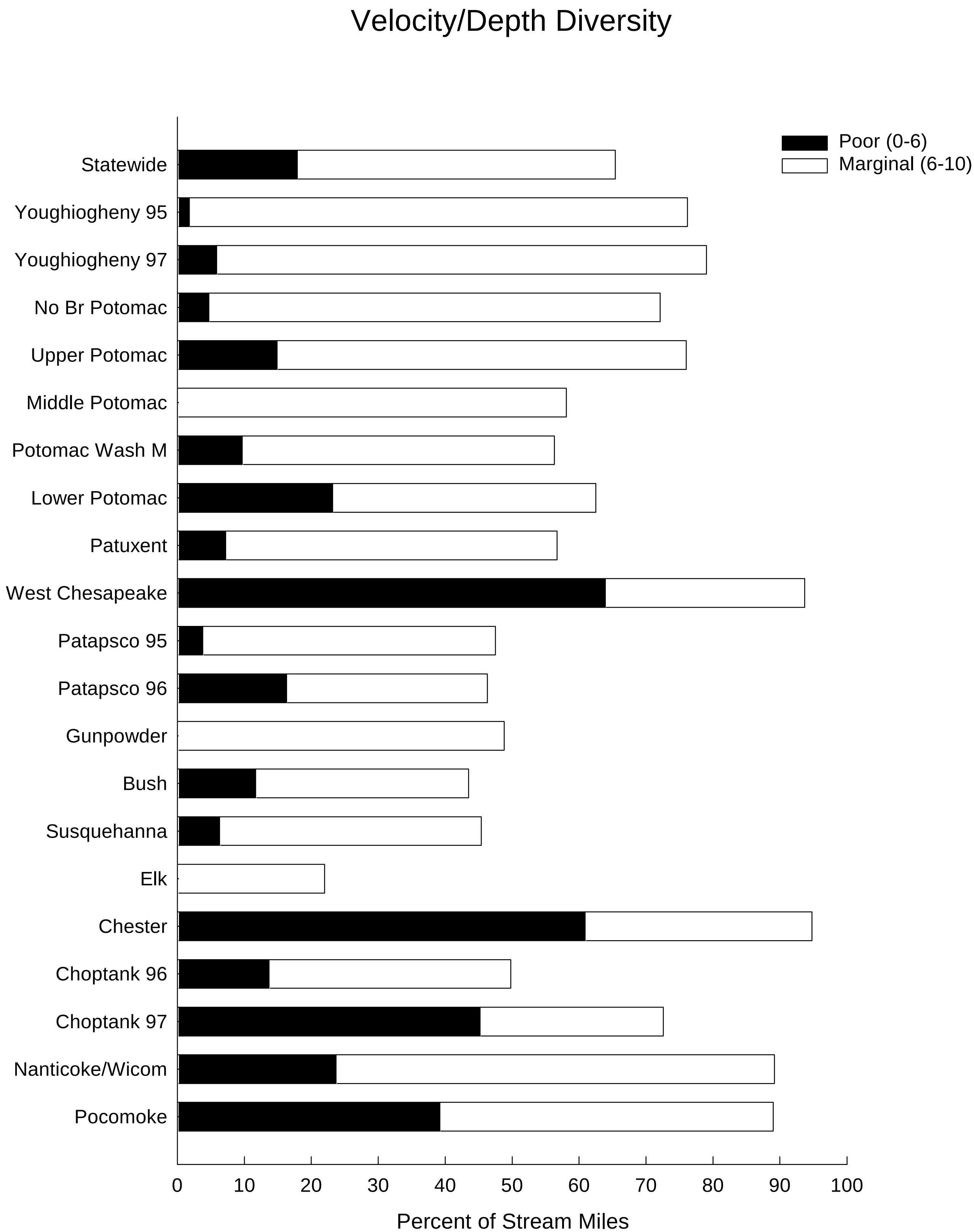


Figure 7-9. Percentage of stream miles with poor and marginal velocity/depth diversity, statewide and for the basins sampled in the 1995-1997 MBSS

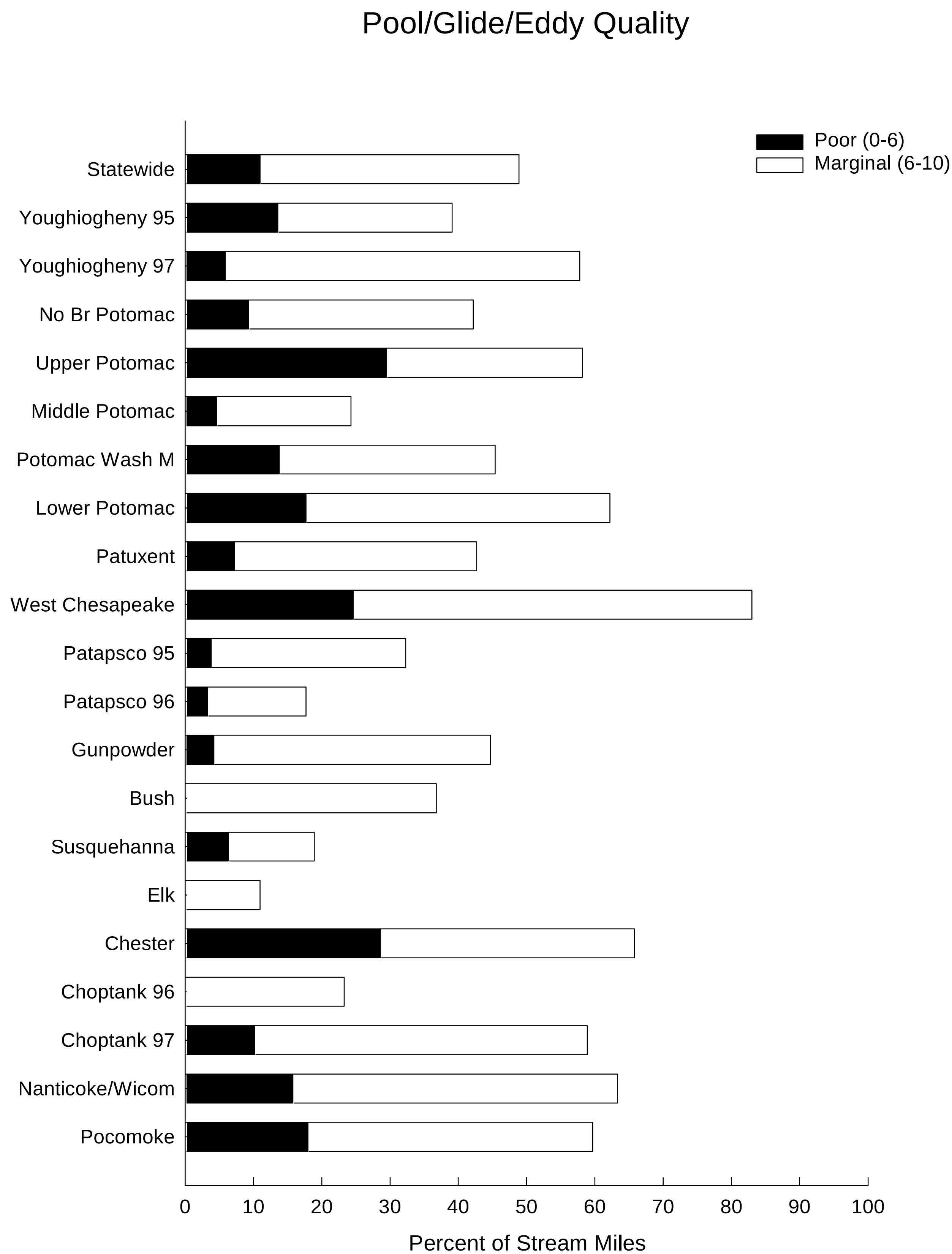


Figure 7-10. Percentage of stream miles with poor and marginal pool/glide/eddy quality, statewide and for the basins sampled in the 1995-1997 MBSS

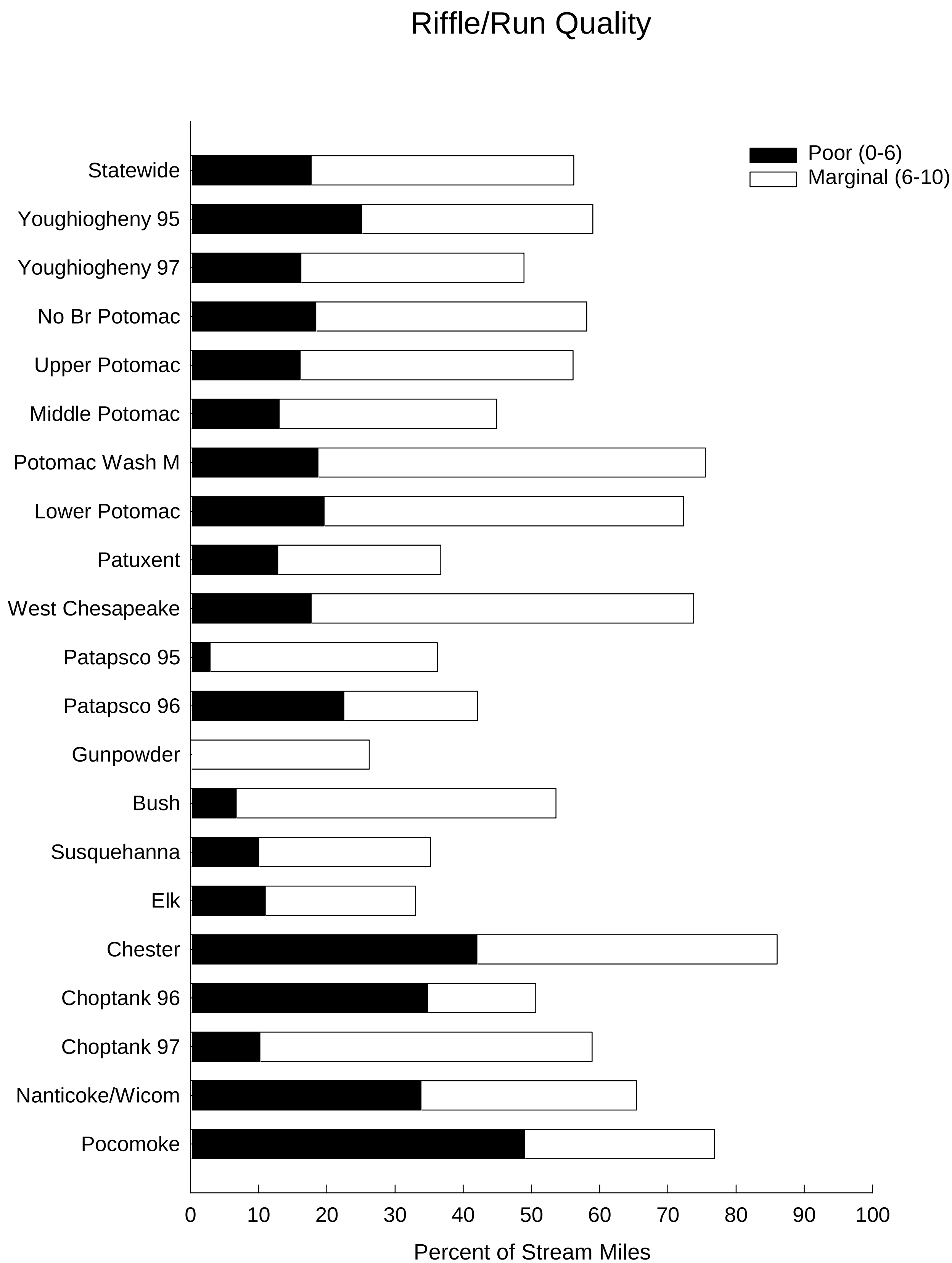


Figure 7-11. Percentage of stream miles with poor and marginal riffle/run quality, statewide and for the basins sampled in the 1995-1997 MBSS

in the Coastal Plain may be lower than for an unimpacted Appalachian stream, because Coastal Plain streams typically are lower gradient and lack cobble/gravel substrates. These comparisons are further complicated by uncertainty about what natural Coastal Plain streams were like prior to European settlement.

The instream habitat structure parameter represents the amount of stable habitat structure in a stream, i.e., cobbles, boulders, logs, undercut banks, rootwads, aquatic plants, and other materials providing habitat and cover for fish. Statewide, a modest percentage of stream miles had either poor (12%) or marginal (28%) instream habitat structure, while 22% were rated as optimal and 38% as suboptimal. Among the basins, the greatest proportions of poor to marginal instream habitat structure (Figure 7-7) were found in the Nanticoke/Wicomico, Chester, and Patuxent basins, where 74, 70, and 66% of stream miles, respectively, fell within this range. In contrast, the Youghiogheny (1997 sampling) had no poor or marginal areas of instream habitat and the Choptank (1996 sampling), Susquehanna, and Elk basins had no poor areas and only 1, 6, and 11% of their respective stream miles listed as marginal. The Bush basin also had no poor-rated habitat, but had 55% marginal instream habitat structure.

Epifaunal substrate is based on the amount and variety of hard stable substrates available to benthic macroinvertebrates (i.e., substrates free of fine sediments or flocculent material). Statewide, nearly half of the stream miles had poor (31%) to marginal (17%) epifaunal substrate (Figure 7-8). The Chester basin had the greatest proportion of poor to marginal epifaunal substrate stream miles (88%). The Nanticoke/Wicomico, Upper Potomac, Lower Potomac, and Pocomoke had poor to marginal epifaunal substrate in greater than 65% of stream miles. Conversely, the Gunpowder and Susquehanna basins had no poor epifaunal substrate and 24% and 15% stream miles of marginal epifaunal substrate, respectively. Low scores for epifaunal substrate may indicate erosion and sedimentation.

Velocity/depth diversity assesses the variety of velocity and depth regimes in the stream segment (slow-shallow, slow-deep, fast-shallow, and fast-deep) and reflects the heterogeneity of available riffle and pool microhabitats. Statewide, poor conditions were present in 12% of the stream miles, while marginal conditions were more common, occurring in 48% of the stream miles (Figure 7-9). Four basins, the Chester (95%), West Chesapeake (94%), Nanticoke/Wicomico (89%), and Pocomoke (89%), each had at least 85% of their stream miles with poor to marginal velocity/depth diversity. Two of these basins, West Chesapeake (64%) and Chester (61%), had poor velocity depth diversity in greater than 60% of their stream miles. The Elk basin had the smallest percentage of stream miles in poor to marginal velocity/depth diversity categories, with no poor stream miles and only 22% marginal. Two other basins had no poor stream miles. Both basins had approximately half their stream miles marginal with 58% and 49%, respectively.

Pool/glide/eddy quality represents the variety, extent, and spatial complexity of slow- or still-water habitat available. Pool/glide/eddy quality, shown in Figure 7-10, was rated as poor in 10% and marginal in 31% of stream miles, statewide. One basin, the West Chesapeake, had 83% of stream miles rated as poor to marginal. Seven other basins had between 58% and 65% poor to marginal pool/glide/eddy quality. Two basins, the Elk and the Choptank (1996 sampling) had no poor and only 11% and 25% marginal pool/glide/eddy quality, respectively.

Riffle/run quality is based on the depth, complexity, and functional importance of riffle and run habitat within the sampled segment. According to statewide estimates, riffle/run quality was poor in 16% of stream miles and marginal in 34% (Figure 7-11). The Chester basin had the greatest proportion of poor to marginal riffle/run quality stream miles (83%). Not surprisingly, low riffle/run quality scores were common in the Chester and other coastal plain basins where riffles are naturally less frequent.

Instream condition scores varied with stream size for many of these parameters. Compared to second- and third-order streams, first-order streams tended to receive lower scores for instream habitat structure, epifaunal substrate, velocity/depth diversity, pool/glide/eddy quality, riffle/run quality, as well as channel alteration. This may indicate that first order streams are more degraded, possibly because they are smaller and therefore more sensitive to anthropogenic stress. However, habitat conditions vary with stream size (Vannote et al. 1980), so differences among stream orders are expected. To accommodate for this natural variability, scoring for first-order streams should be adjusted for the different expectations of small stream habitats using more appropriate reference conditions for different stream sizes (as done for geographic regions in the Physical Habitat Index described in Section 7.3.1).

7.2.5 Aesthetic Quality and Remoteness

Aesthetic quality and remoteness are additional components of stream character rated by the Survey. These are assessed (on a 0-20 point scale) by observing the area surrounding each sampled stream segment. Although these components may not directly affect stream biota, they reflect important human values associated with streams. Aesthetic quality characterizes the visual appeal of a site and declines with visible signs of human impact such as trash. Statewide, an estimated 43% of the stream miles were aesthetically pleasing (scoring $\geq$ 16 out of 20). Only 10% were rated as poor and 17% as marginal (Figure 7-12). By basin, the Choptank (5% in 1997 sampling), Gunpowder (11%), and Youghiogheny (11% in 1997 sampling) had the fewest percentage of stream miles rated poor to marginal for aesthetic quality. The Patapsco (56% in 1996 sampling), West Chesapeake (54%), and Nanticoke/Wicomico (50%) basins had the greatest percent stream miles rated poor to marginal.

Remoteness scores were based on a combination of three factors: the distance from the site to the nearest road, accessibility, and evidence of human activity. Over all basins sampled, 17% of the stream miles were difficult to access (scoring $\geq$ 16 out of 20). Twenty-eight percent were rated as moderately easy to access and 29% as easy access (Figure 7-13). The Elk (85%), Potomac Washington Metro (77%), and Patapsco (78% in 1996 sampling) had the greatest percentage of stream miles rated as easy or moderately easy to access. The North Branch Potomac (33%), Choptank (37%) in 1996 sampling, and Lower Potomac (38%) had the fewest stream miles rated as easy or moderately easy to access.

In general, aesthetic quality and remoteness ratings were positively correlated ($p < 0.0001$, $r^2=0.28$; Figure 7-14). This correlation is not surprising, given that the more difficult a site is to access, the less likely it will show signs of human disturbance.

7.2.6 Quantity of Available Physical Habitat

In addition to varying in habitat quality, streams may differ simply in the amount of physical habitat available to aquatic organisms. Larger streams naturally provide more riffles, pools, and other desirable habitat locations for fish to use for spawning, feeding, and shelter. Conversely, small streams with plentiful shallow riffle habitat may support a greater density and diversity of benthic invertebrates. Although the sites sampled in the Survey were all wadeable streams, they did vary in size from small streams (as shallow as 6 cm and less than 1 meter across) to much larger streams (as deep as 2 meters and more than 20 meters across). Several field measures of stream habitat quantity were made during the 1995-1997 MBSS to compare these differences.

Data on wetted width, average thalweg depth, discharge, and the number of pieces of woody debris and rootwads were collected in each stream segment and summarized in statewide and basin estimates. These data represent conditions throughout first-, second-, and third-order streams, but may not fully characterize the population of all streams in a single basin, particularly in basins with small sample size.

Mean stream width ranged from 2.3 m at first-order streams to 8.8 m at third-order streams. Mean stream width in most basins was between 2 and 5 m, with statewide mean of 3.4 m. Exceptions were the Elk (mean 7.8 m), Bush (5.8 m) and West Chesapeake (1.6 m) basins (Figure 7-15).

Mean thalweg depth (the depth at the deepest part of the channel, measured at four cross-sections per sampled segment) ranged from 16.8 cm in first-order streams to 41.8 cm in third-order. Streams in the western Maryland basins (Youghiogheny, North Branch Potomac, and Upper Potomac) were shallower on average than the statewide mean of 21.9 cm (Figure 7-16). Streams sampled in the Elk basin were the deepest (41.3 cm), while West Chesapeake streams were the shallowest (13.4 cm).

Stream discharge is another measure of stream size, as discharge tends to increase with watershed area, stream width, and depth. Although the Survey collected only one-time discharge data, these data provide a useful comparison of conditions across a large number of sites. Statewide, mean discharge was 2.7 cfs (cubic feet per second). First-order streams sampled had a mean discharge of 0.8 cfs, second-order 4.5 cfs, and third-order 12.6 cfs. Streams in the Elk basin exhibited the highest mean discharge (13.3 cfs), and Chester basin the lowest (0.4 cfs) (Figure 7-17).

Rootwads and other types of woody debris provide habitat, cover, and shade for a variety of stream biota. When riparian forests are removed, this important source of woody debris is lost. To assess the availability of this habitat feature, the numbers of rootwads and other woody debris within each 75-m segment were recorded by MBSS field crews. Statewide, the mean number of wood pieces per segment was about 4. The greatest amount was found in the Chester basin (10.3); other Eastern Shore basins had mean values of at least 5 pieces per segment (Figure 7-18). The lowest mean number of pieces per segment were recorded in the Youghiogheny (1.7 in 1997 sampling), Upper Potomac (1.9), and North Branch Potomac (1.9) basins.

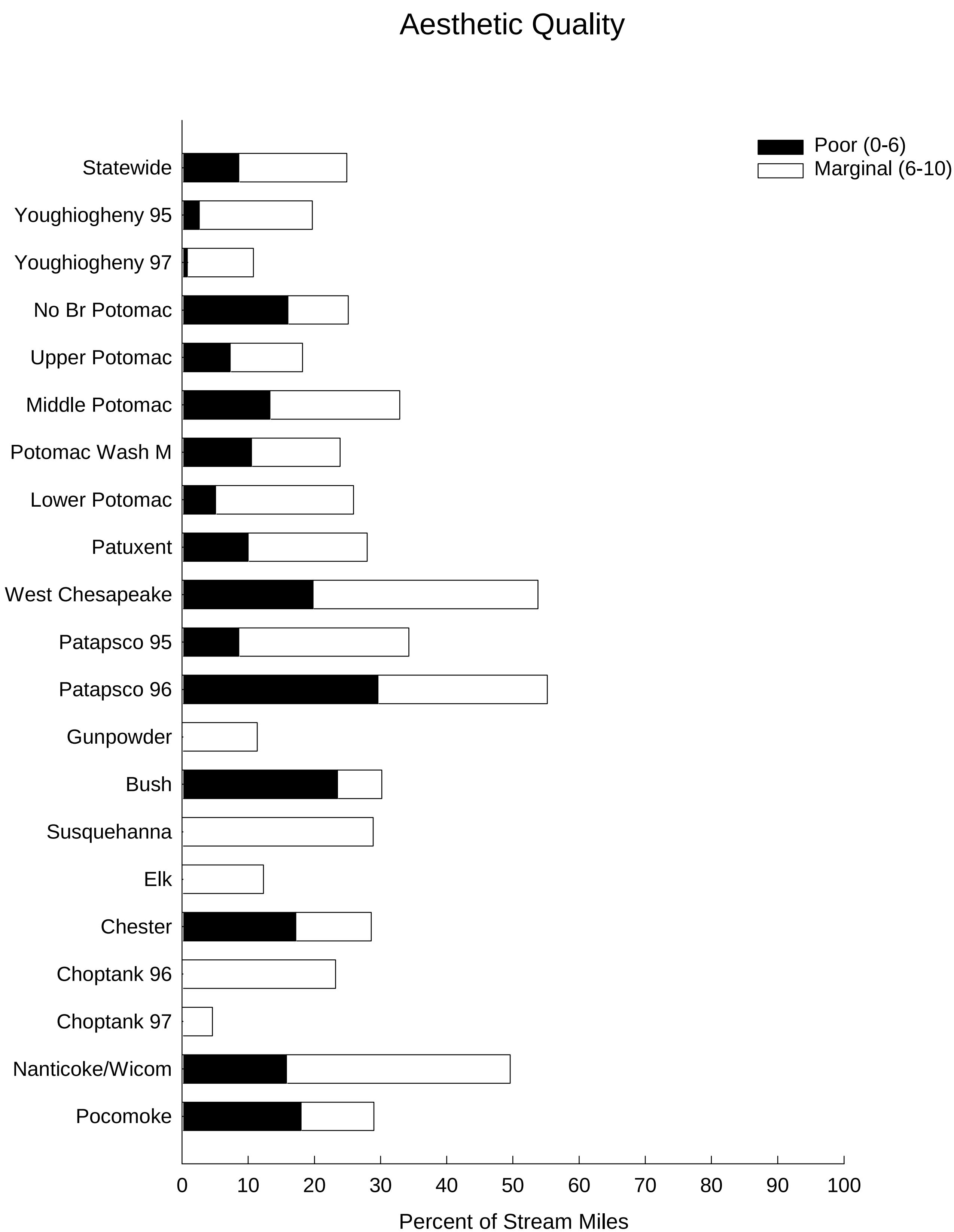


Figure 7-12. Percentage of stream miles with poor and marginal aesthetic quality, statewide and for the basins sampled in the 1995-1997 MBSS

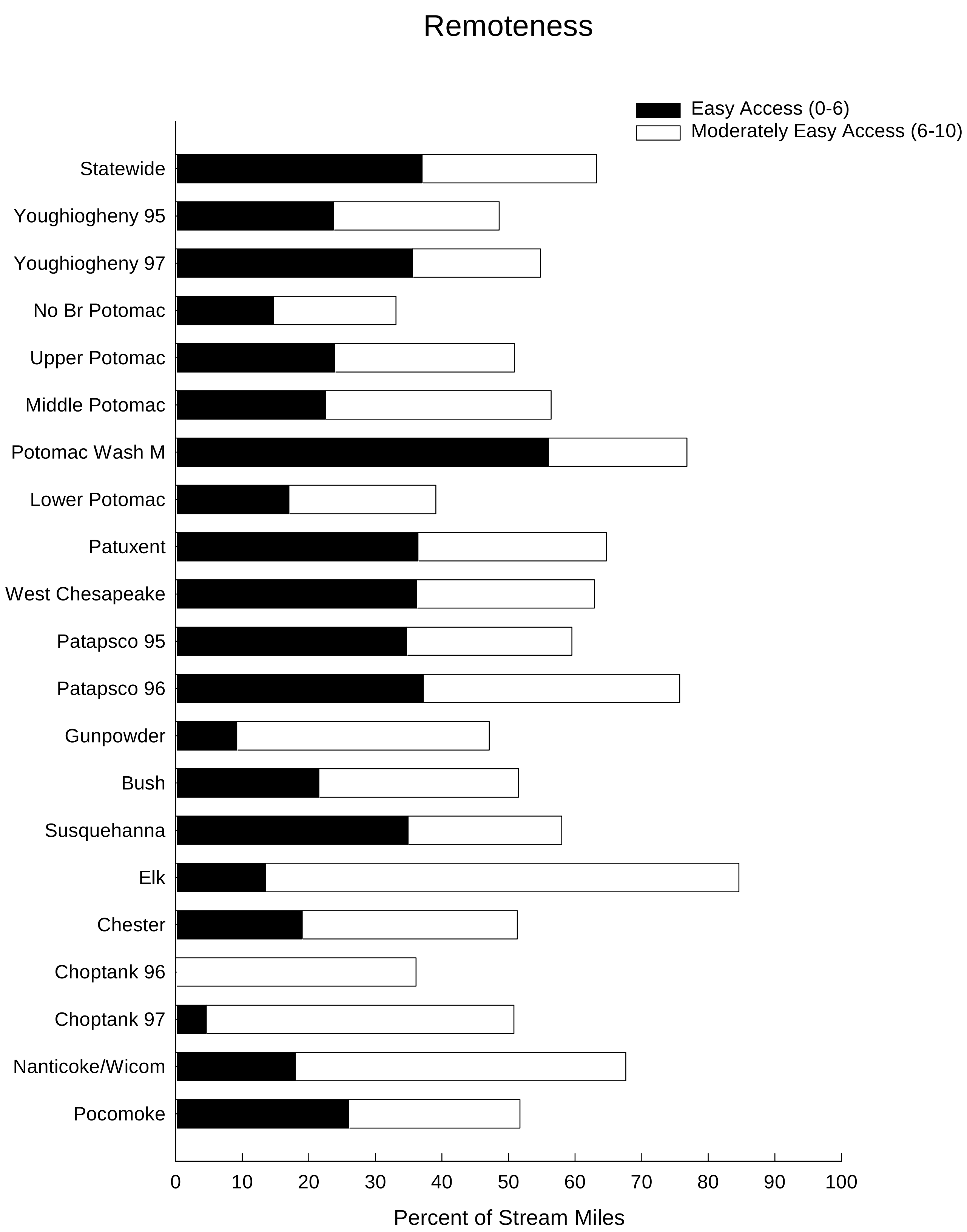


Figure 7-13. Percentage of stream miles rated as easy and moderately easy access, statewide and for the basins sampled in the 1995-1997 MBSS

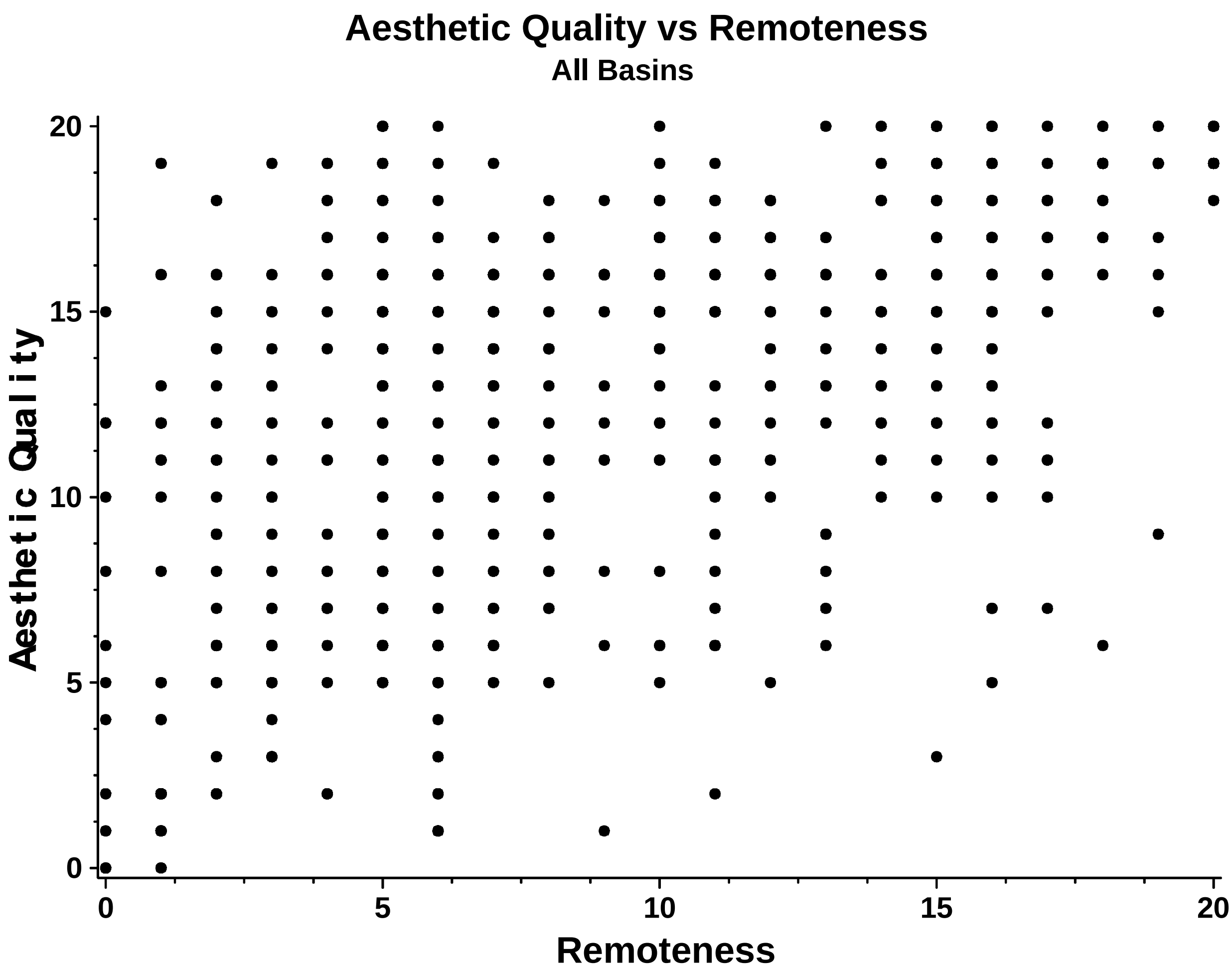


Figure 7-14. Relationship between aesthetic quality and remoteness, statewide, for the 1995-1997 MBSS

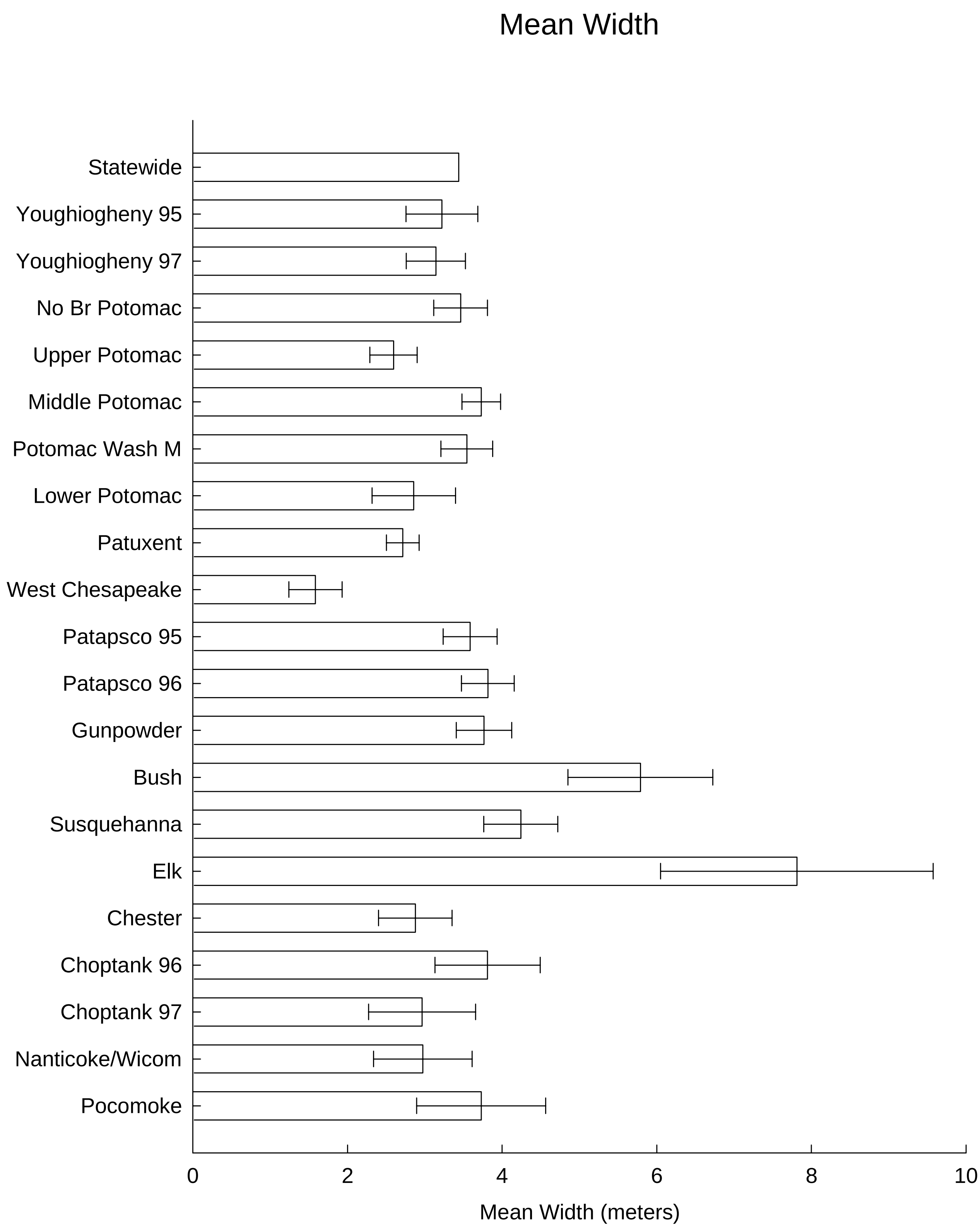


Figure 7-15. Mean stream width, statewide and for the basins sampled in the 1995-1997 MBSS (lack of error bars indicate that variance is statistically undefined)

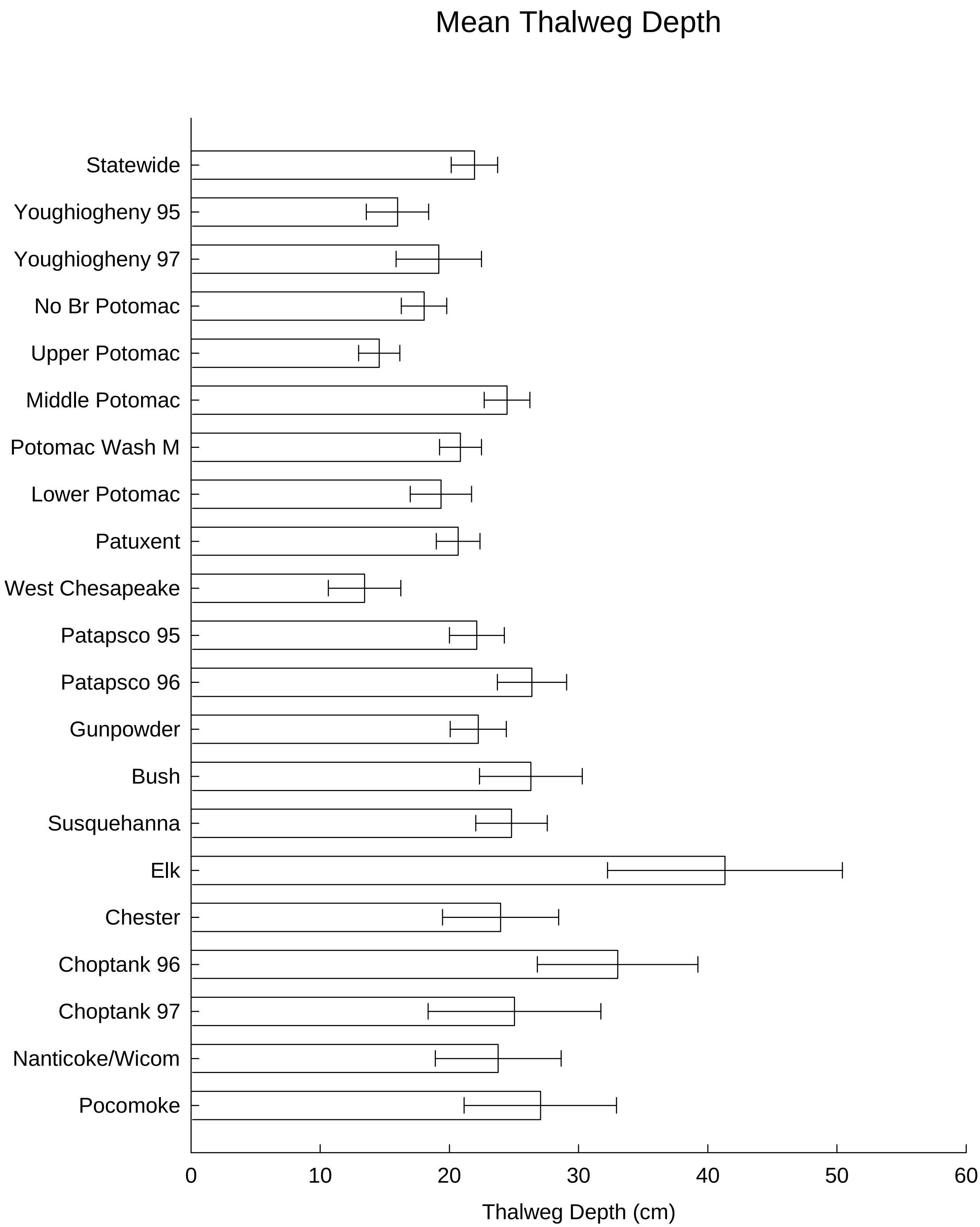


Figure 7-16. Mean thalweg depth, statewide and for the basins sampled in the 1995-1997 MBSS

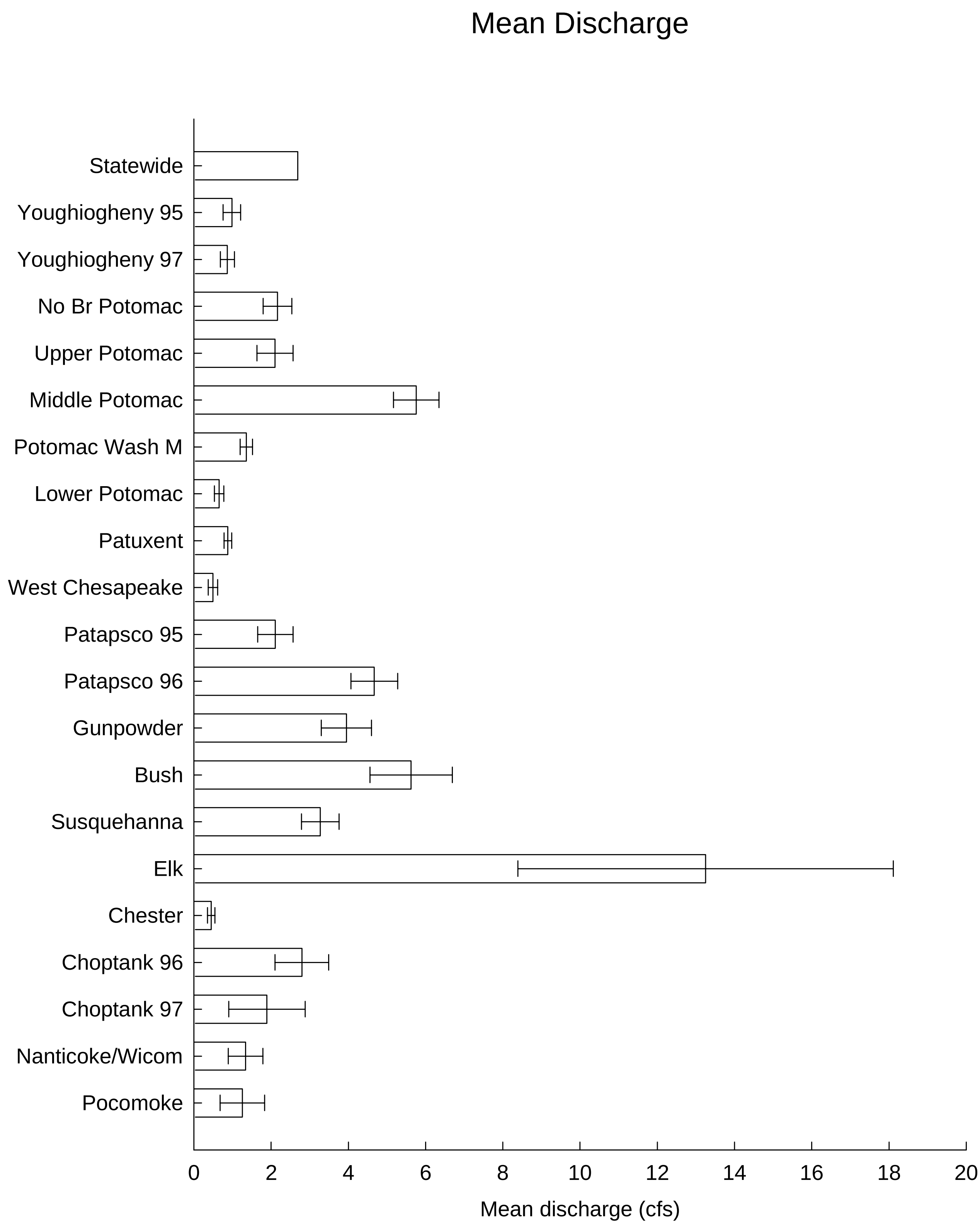


Figure 7-17. Mean discharge, statewide and for the basins sampled in the 1995-1997 MBSS (lack of error bars indicate that variance is statistically undefined)

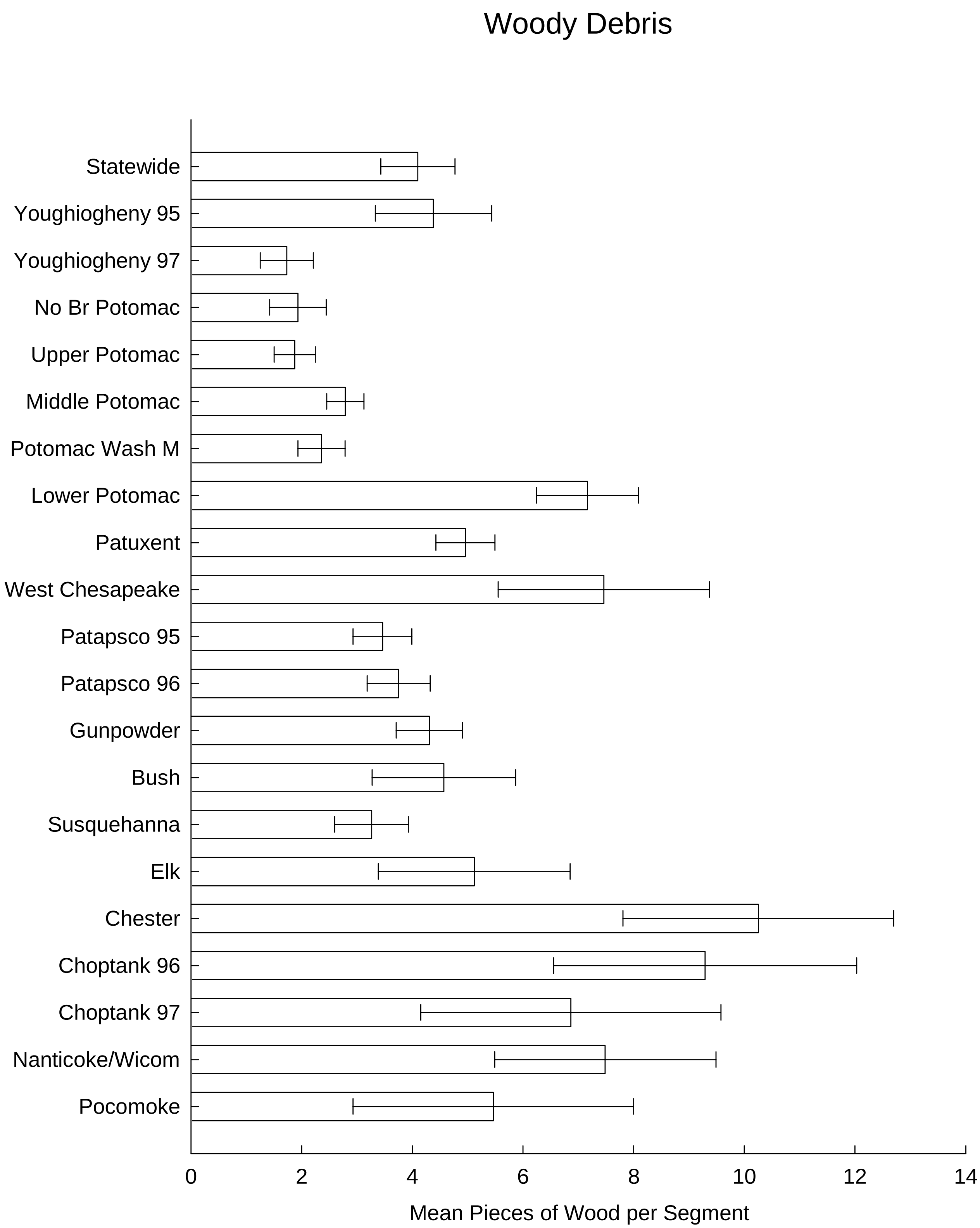


Figure 7-18. Mean number of pieces of wood found in the stream, statewide and for the basins sampled in the 1995-1997 MBSS. Number of pieces of wood includes both rootwads and large woody debris.

7.3 PHYSICAL HABITAT INDEX

The physical habitat component of freshwater streams strongly influences the composition and status of stream fish communities (Gorman and Karr 1978). Because physical habitat is such an important factor, it was assessed concurrently with fish sampling during the MBSS sampling. As described earlier, procedures for physical habitat assessment were derived from two sources: EPA's Rapid Bioassessment Protocols (RBPs) (Plafkin et al. 1989) as modified by Barbour and Stribling (1991), and the Ohio EPA's Qualitative Habitat Evaluation Index (Rankin 1989). In addition to the 13 qualitative physical habitat metrics derived from these methods, additional qualitative and quantitative stream characteristics (meandering, presence of emergent and submergent vegetation, presence of coarse woody debris, rootwad number, etc.) were recorded during MBSS field sampling. All of the measured parameters were considered in the development of a reference-based indicator of physical habitat conditions in Maryland streams.

7.3.1 Development of the Physical Habitat Index

The Physical Habitat Index (PHI) for Maryland was developed using MBSS data from 1994 to 1997 (including data from the 1994 demonstration project; Hall et al. 1999b). As was the case in development of the fish and benthic IBIs, the conceptual approach was based on evaluating the relative importance (discriminatory power) of individual metrics and combinations of metrics for explaining natural differences in streams throughout Maryland. Based on analyses conducted for both fish IBI (Roth et al. 1998) and benthic IBI (Stribling et al. 1998) development in Maryland, the State was divided into two regions: the Coastal Plain and non-Coastal Plain. These two geographic strata are consistent with aggregations of ecoregions (Omernik 1987) or physiographic provinces developed for Maryland (Reger 1995). Separate PHIs were developed for each stratum.

As was the case with the fish and benthic IBIs, the approach to developing the PHI consisted of the following five steps: (1) developing and organizing the data base, (2) scaling and evaluating the distribution of various metrics, (3) identifying reference and degraded sites, (4) assessing the discriminatory power of physical habitat metrics and stream characteristics, and (5) combining metrics into an index. Step 2 addressed the fact that some metrics (e.g., instream habitat structure and remoteness) use a scale of 0 to 20, other metrics use a percentage (e.g., percent embedded), and still others use a direct measure (e.g., riparian width in meters), by converting each metric to a common scale. Each metric was grouped into the following categories: structural, hydrological, vegetative, and visual appeal.

In step 3, reference and degraded sites were determined using the same criteria applied in developing the fish and benthic IBIs, minus the physical habitat criteria. In addition, the relationships of selected metrics, appropriate stream characteristics, and quantitative variables (e.g., discharge) to fish IBI scores or individual fish IBI metrics (e.g., species richness and abundance) were determined. Based on these results, criteria designating high and low biological integrity were added for determining reference and degraded sites.

After analyzing the discriminatory power of individual metrics and composite indices, the Coastal Plain PHI was defined as follows:

$$\text{PHI} = \frac{\text{INSTREAM HABITAT STRUCTURE} + \text{VELOCITY/DEPTH DIVERSITY} + \text{POOL QUALITY} - \text{EMBEDDEDNESS}/10 + \text{MAXIMUM DEPTH}/10 + \text{AESTHETIC QUALITY}/2}{6}$$

The non-Coastal Plain PHI was defined as follows:

$$\text{PHI} = \frac{\text{INSTREAM HABITAT STRUCTURE} + \text{VELOCITY/DEPTH DIVERSITY} + \text{RIFFLE QUALITY} - \text{EMBEDDEDNESS}/10 + 3 \text{ X (NUMBER OF ROOTWADS)} + \text{AESTHETIC QUALITY}/3}{6}$$

Four key physical habitat variables were common between both the Coastal Plain and the non-Coastal Plain: (1) instream habitat structure; (2) velocity/depth diversity; (3) embeddedness; and (4) aesthetic rating. Two additional variables were important in the Coastal Plain – pool/glide/eddy quality and maximum depth. Two other variables were important in the non-Coastal Plain – riffle/run quality and number of rootwads in a stream reach.

The index was then adjusted to a centile scale that rated each sample segment as follows:

- Scores of 72 to 100 are rated good
- Scores of 42 to 71.9 are rated fair
- Scores of 12 to 41.9 are rated poor
- Scores of 0 to 11.9 are rated very poor

7.3.2 Physical Habitat Index Results

Twenty percent of stream miles statewide had a PHI rating of good. The largest percentage of stream miles were in either fair (29%) or poor (29%) physical habitat condition (Figures 7-19 and 7-20). An estimated 22% of stream miles were in very poor condition.

PHI scores tended to increase with stream order. The statewide mean PHI score in first-order streams was 34, compared to a mean score of 57 in second-order and 67 in third-order streams. A far greater percentage of first-order stream miles were rated as very poor (29%) and poor (34%) than were second- or third-order counterparts. While the PHI rated 71% of second-order stream miles and 84% of third-order stream miles as good to fair, only 36% of first-order stream miles received that rating (Table 7-1). The lower ratings for first-order streams likely reflect the greater diversity of physical habitat available in larger streams. Many of the parameters in the PHI (e.g., instream habitat structure, velocity/depth diversity) tend to have higher scores in larger streams. The degree to which low scores are an artifact of stream size difference or, alternatively, indicate more degraded physical habitat in first-order streams, remains a question for further investigation. Because first-order streams make up the overwhelming majority of stream miles in Maryland, first-order stream results strongly influence the overall picture of stream conditions statewide and within basins.

The geographic distribution of PHI scores at sampled sites is shown on a statewide map (Figure 7-19). Sites with good PHI scores were found in all basins, although the greatest concentration was in the central Maryland Piedmont. Surprisingly, Western Maryland had a large concentration of sites rated poor or very poor by the PHI. This may reflect the prevalence of smaller streams in western Maryland, especially when compared to larger Piedmont streams found in the same PHI region (non-Coastal Plain).

Differences in PHI among basins (Figures 7-20 and 7-21, Table 7-1) were consistent with results for individual instream condition parameters (see section 7.2.4). The Elk basin, with 56% of stream miles in good condition, was a marked contrast to the Nanticoke/Wicomico, where 50% of stream miles were in very poor condition. No sites in the Elk or Choptank (1996 sampling) basins had PHI scores in the very poor range. The basins with the greatest percentage of stream miles in good to fair condition were the Elk (89%), Choptank (75% in 1996 sampling), Susquehanna (75%), Patapsco (71% in 1995 sampling), Bush (65%), and Gunpowder (64%). Each of these basins, except the Patapsco, had no poor or poor-to-marginal stream miles for at least one of the instream condition parameters evaluated in Section 7.2.4.

The basins with the greatest extent of poor and very poor physical habitat were the West Chesapeake (78%), Nanticoke/Wicomico (77%), Upper Potomac (73%), Youghiogheny (68% in both 1995 and 1997 sampling), Chester (68%), and North Branch Potomac (65%). In the West Chesapeake basin, individual instream condition parameters showed few miles with optimal habitat, especially for epifaunal substrate, velocity/depth diversity, pool/glide/eddy quality, and riffle/run quality. Other physical habitat parameters–bank stability, riparian buffer width, aesthetic quality, and remoteness–all had more than 25% of stream miles rated as optimal. This is one example of different individual parameters providing different assessments, indicating how different parameters factor into the overall PHI score. It should also be noted that the West Chesapeake streams sampled were generally smaller than average, whereas Elk streams (which tended to receive higher PHI scores) were larger than the statewide mean (see Section 7.2.6).

Mean PHI scores provide another basis of comparison among basins. The statewide mean PHI was 42. No basin had a mean PHI in the good range (≥ 72). The highest mean PHI scores were reported in the Elk (71) and Choptank (65 in 1996 sampling). Other mean PHI estimates for basins fell between 26 and 55, corresponding with ratings of poor to fair.

7.4 ASSOCIATIONS BETWEEN PHYSICAL HABITAT DEGRADATION AND BIOLOGICAL CONDITION

The PHI scores were compared with fish IBI scores, benthic IBI scores, and the Hilsenhoff Biotic Index for each basin and statewide to identify whether an association exists between physical habitat quality and biotic integrity. For each statewide and basin comparison, regression analyses were used to compare the PHI and biological indicatorscores. PHI and IBI scores were also plotted against each other to investigate relationships between these indicators.

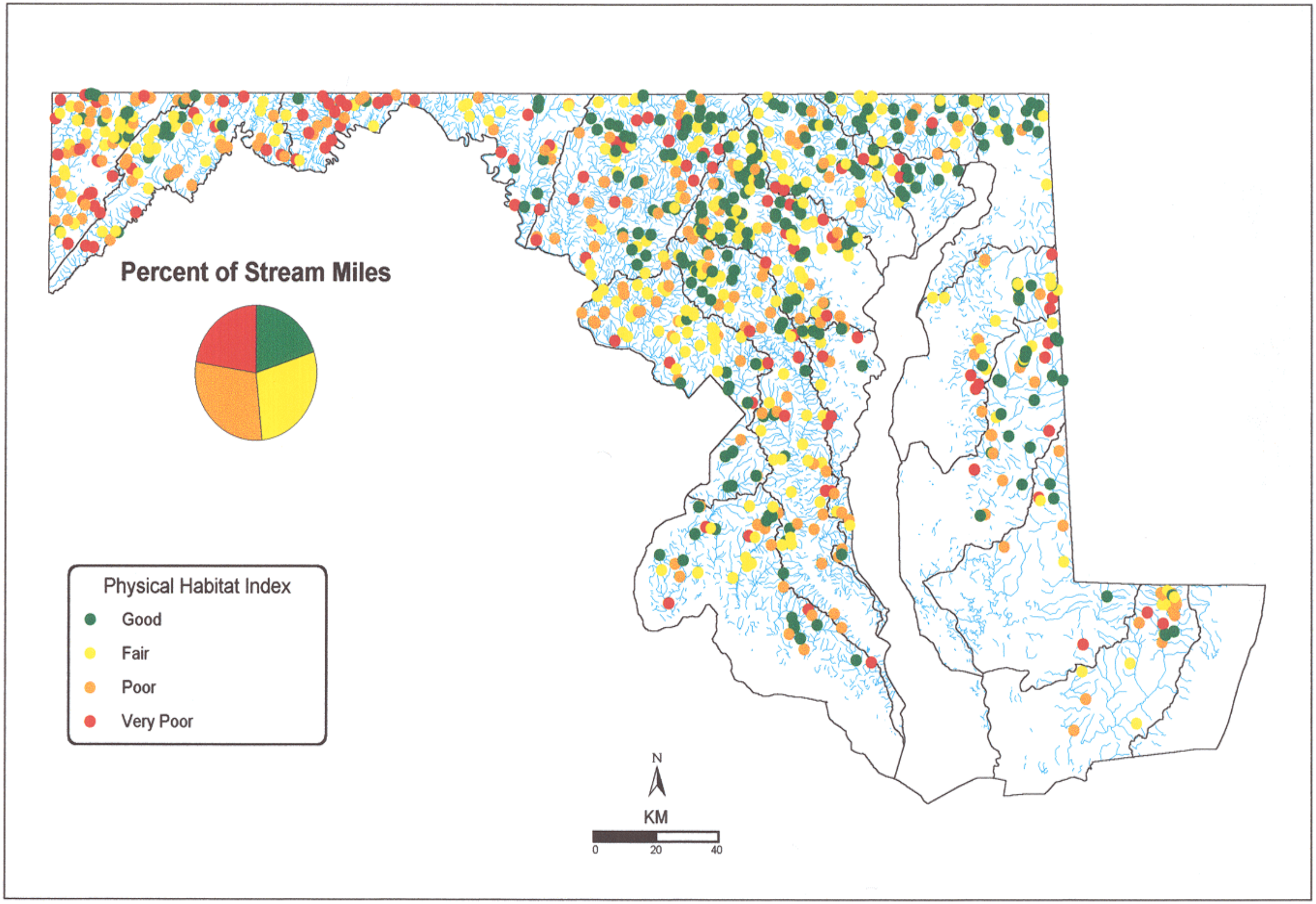


Figure 7-19. Geographic distribution of Physical Habitat Index (PHI) ratings for sites sampled in the 1995-1997 MBSS. Ratings are as follows: 72-100 good, 42-71.9 fair, 12 -41.9 poor, and 0-11.0 very poor.

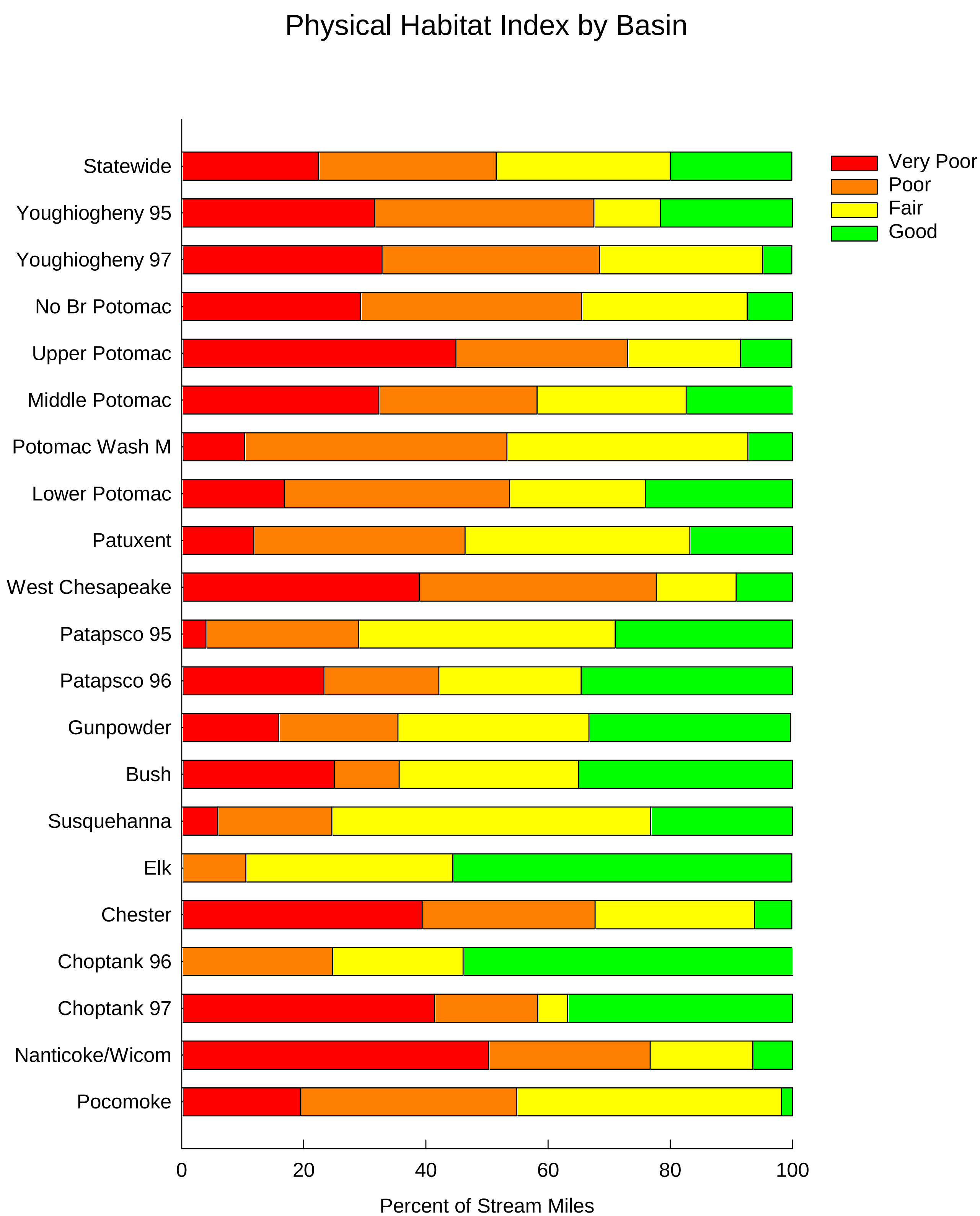


Figure 7-20. Physical Habitat Index (PHI) ratings for the basins sampled in the 1995-1997 MBSS, as the percentage of stream miles in each category. Ratings are as follows: 72-100 good, 42-71.9 fair, 12 -41.9 poor, and 0-11.0 very poor.

Table 7-1. Estimated percentage of stream miles in each PHI category for basins sampled in the 1995-1997 MBSS

	Good	**Std. Error**	**Fair**	**Std. Error**	**Poor**	**Std. Error**	**Very Poor**	**Std. Error**
Basin								
Youghiogheny 1995	21.6	9.1	10.9	6.8	35.9	11.6	31.6	11.5
Youghiogheny 1997	4.8	2.5	26.7	7.2	35.6	11.3	32.8	11.2
North Branch Potomac	7.4	2.7	27.1	6.8	36.2	9.3	29.3	9.2
Upper Potomac	8.4	2.4	18.5	6.1	28.1	7.7	44.9	8.8
Middle Potomac	17.5	2.6	24.4	5.4	25.9	6.0	32.3	6.8
Potomac Washington Metro	7.3	1.9	39.4	7.7	43.0	8.5	10.3	5.3
Lower Potomac	24.1	7.1	22.2	7.7	36.9	9.8	16.8	7.5
Patuxent	16.8	4.2	36.8	6.9	34.6	6.9	11.8	4.8
West Chesapeake	9.2	3.2	13.1	8.1	38.8	14.7	38.9	15.7
Patapsco 1995	29.0	6.6	42.0	8.7	25.0	7.8	4.0	3.4
Patapsco 1996	34.6	7.2	23.3	6.6	18.8	6.8	23.3	7.5
Gunpowder	33.2	8.5	31.3	8.5	19.5	7.7	15.9	7.4
Bush	35.0	12.4	29.4	14.8	10.6	10.6	25.0	14.6
Susquehanna	23.2	6.9	52.2	12.6	18.7	9.6	5.9	5.9
Elk	55.5	17.4	33.9	16.8	10.5	10.5	0.0	0.0
Chester	6.1	2.7	26.1	8.9	28.3	10.9	39.4	13.0
Choptank 1996	54.0	17.2	21.4	14.4	24.7	14.8	0.0	0.0
Choptank 1997	36.8	16.8	4.9	2.9	16.9	10.9	41.4	18.2
Nanticoke/Wicomico	6.5	2.9	16.8	11.5	26.4	13.8	50.3	17.7
Pocomoke	1.8	0.9	43.3	17.3	35.5	15.7	19.4	13.2
Stream Order								
1	10.9	4.8	25.8	9.4	34.2	5.3	29.1	9.8
2	36.0	8.1	35.0	6.5	19.6	5.8	9.4	5.9
3	50.0	12.7	34.2	14.6	13.1	9.7	2.7	4.0
Statewide	19.9	3.8	28.5	7.4	29.1	3.5	22.4	7.6

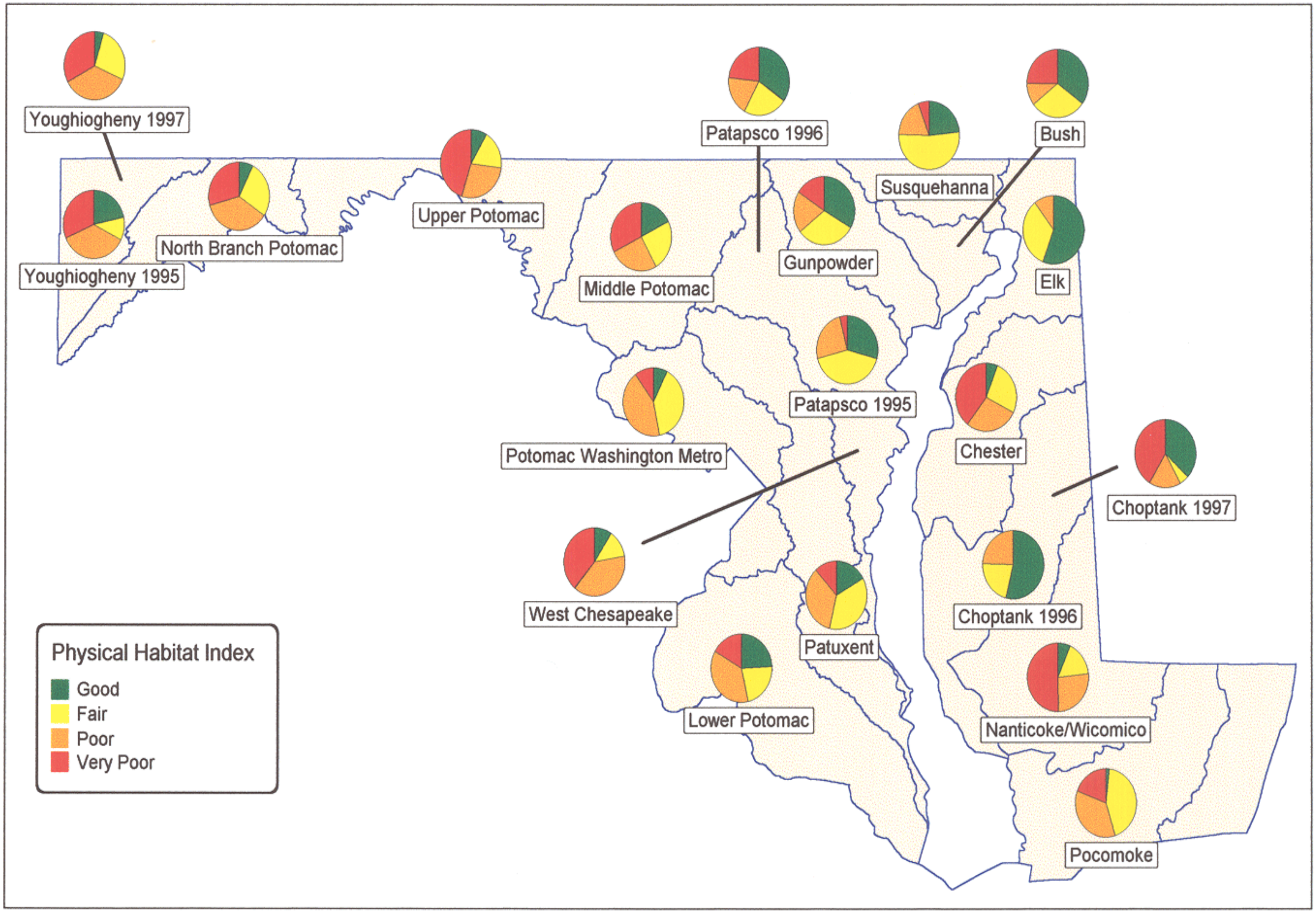


Figure 7-21. Distribution of Physical Habitat Index (PHI) ratings for the basins sampled in the 1995-1997 MBSS as the percentage of stream miles in each category. Ratings are as follows: 72-100 good, 42-71.9 fair, 12 -41.9 poor, and 0-11.0 very poor.

A significant positive relationship was found between the PHI and the fish IBI for all basins (Table 7-2, Figure 7-22). The strength of the relationship varied, but was found to be significant for all basins (linear regression, $p<0.02$), with between 12 and 58% of the variability in the data explained by the relationship between PHI and fish IBI. Statewide, the relationship was significant ($p<0.001$, $r^2=0.28$). The basins with the strongest relationships were the Bush, Nanticoke/Wicomico, Lower Potomac, and Middle Potomac.

There was a significant positive relationship between the PHI and benthic IBI both statewide and in seven individual basins (Table 7-2, Figure 7-23). Statewide, the relationship was significant ($p<0.01$) and 19% of the variability in the data was explained by the relationship between the PHI and benthic IBI. The individual basins for which a significant relationship ($p<0.05$) was found were the Middle Potomac, Lower Potomac, Patuxent, West Chesapeake, Chester, Choptank, and Nanticoke/Wicomico (r^2 values ranging from 0.05 to 0.42).

No significant relationship was found between the PHI and Hilsenhoff Biotic Index when all sites sampled statewide were pooled (Table 7-2). A significant negative correlation was found in three of the basins, the Patuxent, Chester, and Choptank. This overall lack of correlation with the PHI confirms that the Hilsenhoff Biotic Index is most appropriate for assessing organic enrichment in other water chemistry conditions rather than differences in physical habitat conditions.

Although a biotic integrity index has not yet been developed for amphibians and reptiles, presence/absence data on these groups was compared with physical habitat conditions as assessed by the PHI. The number of amphibian and reptile species per site increased with PHI scores. Numbers of both aquatic and terrestrial species increased slightly in areas with good physical habitat, compared to areas of less favorable physical habitat (Figure 7-24). However, these increases were within the range of error for these estimates. Given their affinity for particular habitat features, certain species (e.g., streamside salamanders), may prove to be better indicators of physical habitat quality.

7.5 RELATIONSHIPS BETWEEN INDIVIDUAL PHYSICAL HABITAT FACTORS AND BIOTA

In addition to the associations with the PHI, numerous relationships between biota and individual physical habitat parameters were explored using 1995-1997 MBSS data. Selected examples are presented below.

Given the relationship between fish IBI and PHI scores, further analyses were conducted to determine which individual physical habitat parameters had the strongest associations with the fish IBI. Individual parameters were compared with the fish IBI in box-and-whisker and scatter plots of statewide data. Most of the individual parameters in the PHI showed a relationship with fish IBI scores. For example, fish IBI scores increased with instream habitat structure (Figure 7-25), aesthetic quality (Figure 7-26), and maximum depth (Figure 7-27). Instream habitat structure is a direct assessment of instream conditions important to fish. In contrast, aesthetic quality provides a general rating of the degree of human impact at a site.

Similar plots were constructed to compare individual habitat parameters with benthic IBI scores. Some relationships between habitat and benthic IBI were evident. For example, the benthic IBI increased with riffle quality (Figure 7-28) and aesthetic quality (Figure 7-29). Maximum depth and the abundance of woody debris did not show associations with the benthic IBI. Embeddedness, a factor that would be expected to directly affect benthic habitat, exhibited a great deal of variability with benthic IBI scores. In several basins (Middle Potomac, Potomac Washington Metro, Lower Potomac, Patuxent, Patapsco, and Gunpowder), benthic IBI scores decreased with increased embeddedness, consistent with declines that would occur where sedimentation has degraded stream bottom habitat. In a few basins (Pocomoke, Nanticoke/Wicomico, and West Chesapeake), there was no apparent relationship between IBI scores and embeddedness. High embeddedness scores were common in these basins and appeared to represent natural conditions in silt-bottom streams. This condition would not necessarily be detrimental to benthic species adapted to Coastal Plain streams.

Fish and benthic IBI scores were also compared with a number of physical habitat parameters not included in the overall PHI. As expected, both indices increased slightly with riparian buffer width (Figure 7-30). Benthic IBI scores increased with epifaunal substrate score (Figure 7-31), suggesting this parameter is useful for assessing benthic habitat quality. Both the fish and benthic IBIs decreased with low channel alteration scores, a significant finding given the widespread evidence of channel alteration in Maryland streams.

The presence of riparian buffer vegetation is important to amphibian and reptile species as well. The number of amphibian and reptile species per site increased with riparian buffer width, a pattern followed by both aquatic and terrestrial species (Figure 7-32). Terrestrial amphibian and reptile species were slightly more numerous at forested

Table 7-2. Regression relationships between the Physical Habitat Index and other biological indicators, 1995-1997 MBSS. Only those basins where the relationship was significant are shown.		
Basin	**p value**	**r^2**
PHI and Fish IBI		
Statewide	0.0001	0.28
Youghiogheny	0.0001	0.20
North Branch Potomac	0.0001	0.37
Upper Potomac	0.0018	0.18
Middle Potomac	0.0001	0.43
Potomac Washington Metro	0.001	0.17
Lower Potomac	0.0001	0.43
Patuxent	0.0004	0.17
West Chesapeake	0.0039	0.32
Patapsco	0.0001	0.13
Gunpowder	0.0033	0.23
Bush	0.0004	0.58
Susquehanna	0.0021	0.28
Elk	0.0093	0.37
Chester	0.004	0.32
Choptank	0.0144	0.17
Nanticoke/Wicomico	0.0023	0.50
Pocomoke	0.007	0.29
PHI and Benthic IBI		
Statewide	0.0002	0.02
Middle Potomac	0.0236	0.05
Lower Potomac	0.0001	0.30
Patuxent	0.0009	0.13
West Chesapeake	0.0012	0.30
Chester	0.0001	0.42
Choptank	0.0089	0.18
Nanticoke/Wicomico	0.0165	0.33
PHI and Hilsenhoff Biotic Index		
Patuxent	0.0005	0.16
Chester	0.0009	0.31
Choptank	0.0445	0.11

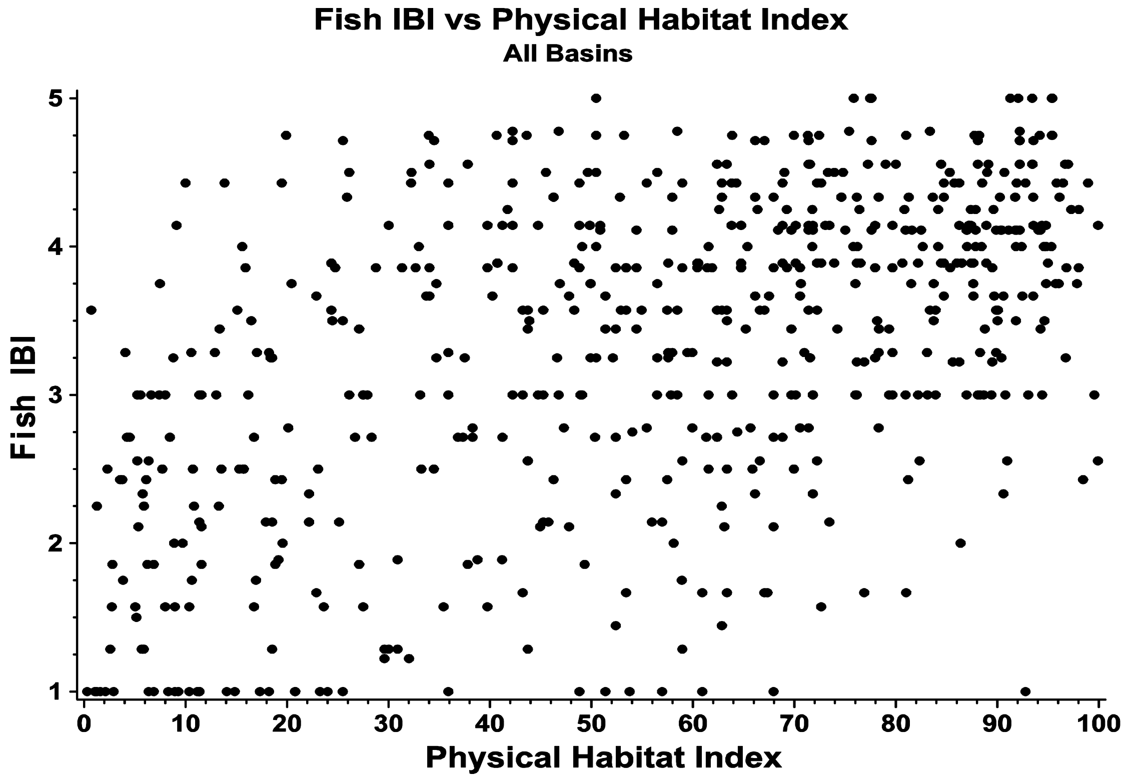


Figure 7-22. Relationship between the fish IBI and the Physical Habitat Index (PHI), statewide for the 1995-1997 MBSS

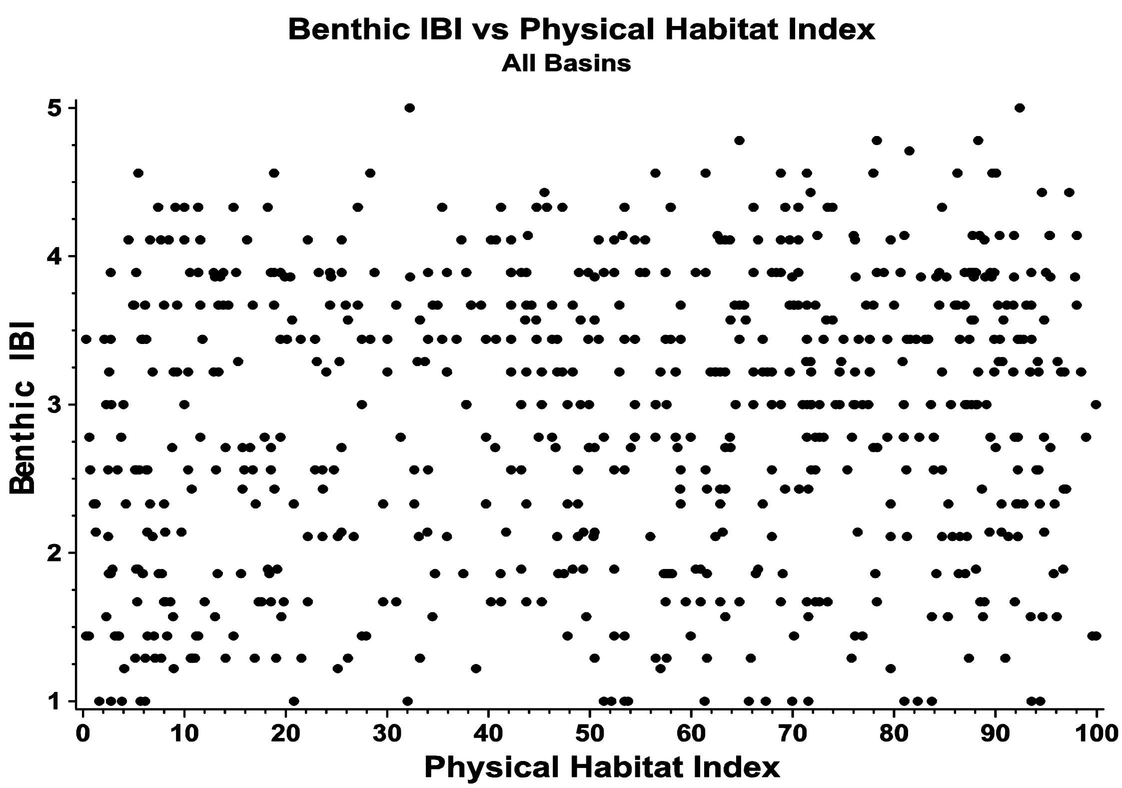


Figure 7-23. Relationship between the benthic IBI and the Physical Habitat Index (PHI), statewide for the 1995-1997 MBSS

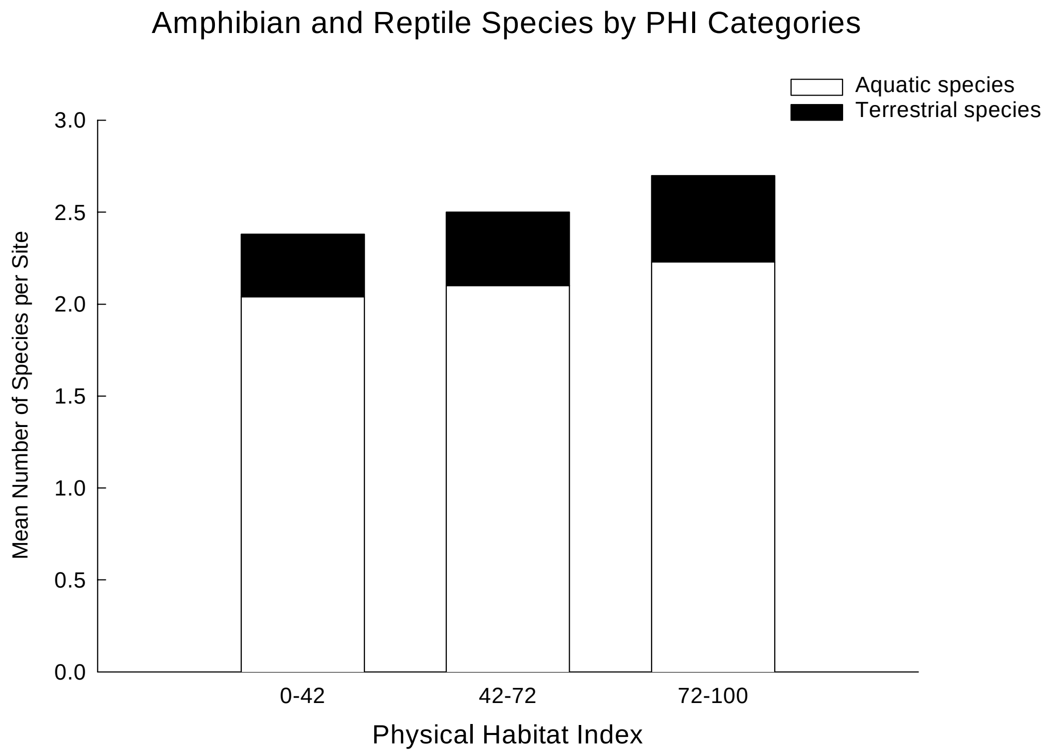


Figure 7-24. Mean number of amphibian and reptile species in three categories of the Physical Habitat Index (PHI) for the 1995-1997 MBSS

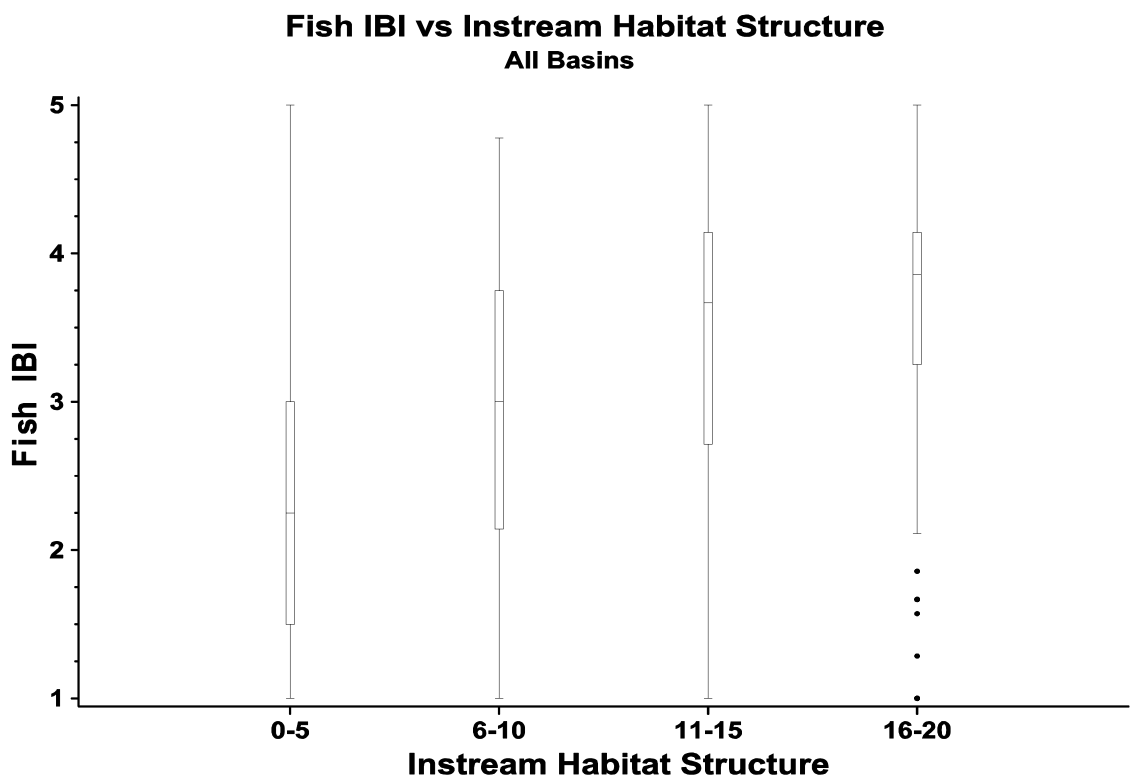


Figure 7-25. Relationship between the fish IBI and instream habitat structure, statewide for the 1995-1997 MBSS. In box-and-whisker plots, the box indicates the 25th percentile, median, and 75th percentile of values. Vertical lines designate the range of values; dots indicate outliers (values beyond 1.5 times the interquartile range).

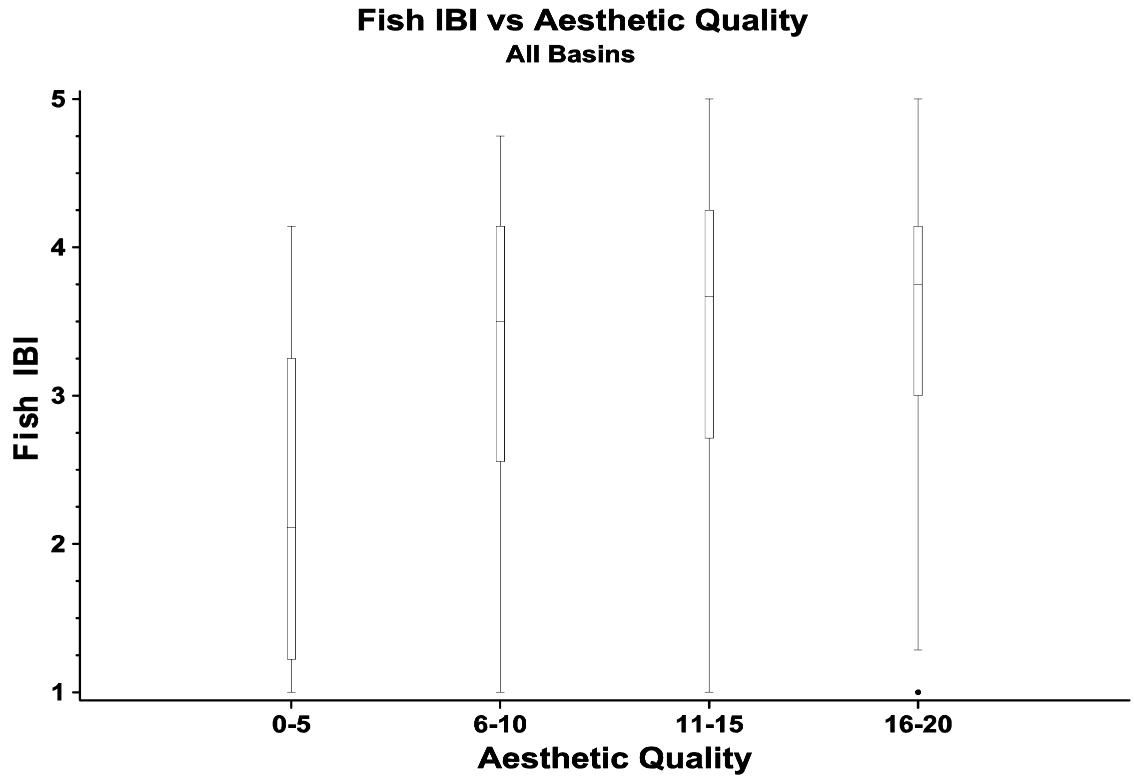


Figure 7-26. Relationship between the fish IBI and aesthetic quality, statewide for the 1995-1997 MBSS

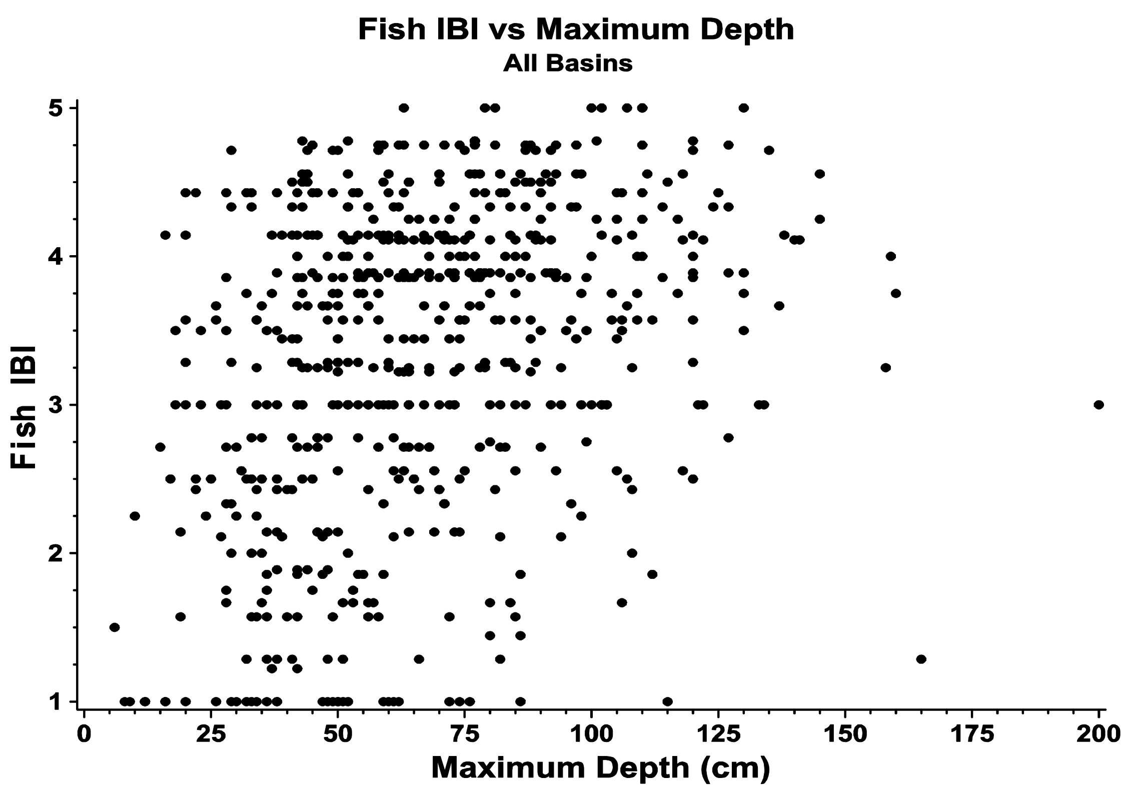


Figure 7-27. Relationship between the fish IBI and maximum depth, statewide for the 1995-1997 MBSS

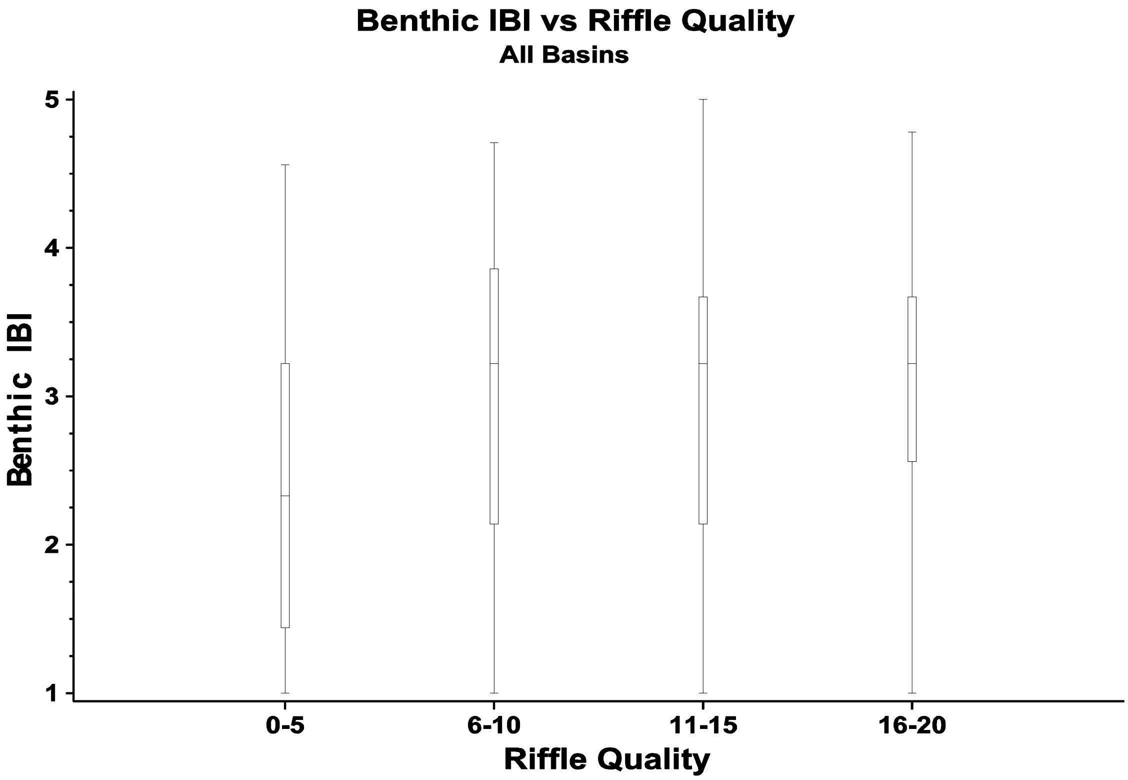


Figure 7-28. Relationship between the benthic IBI and riffle/run quality, statewide for the 1995-1997 MBSS

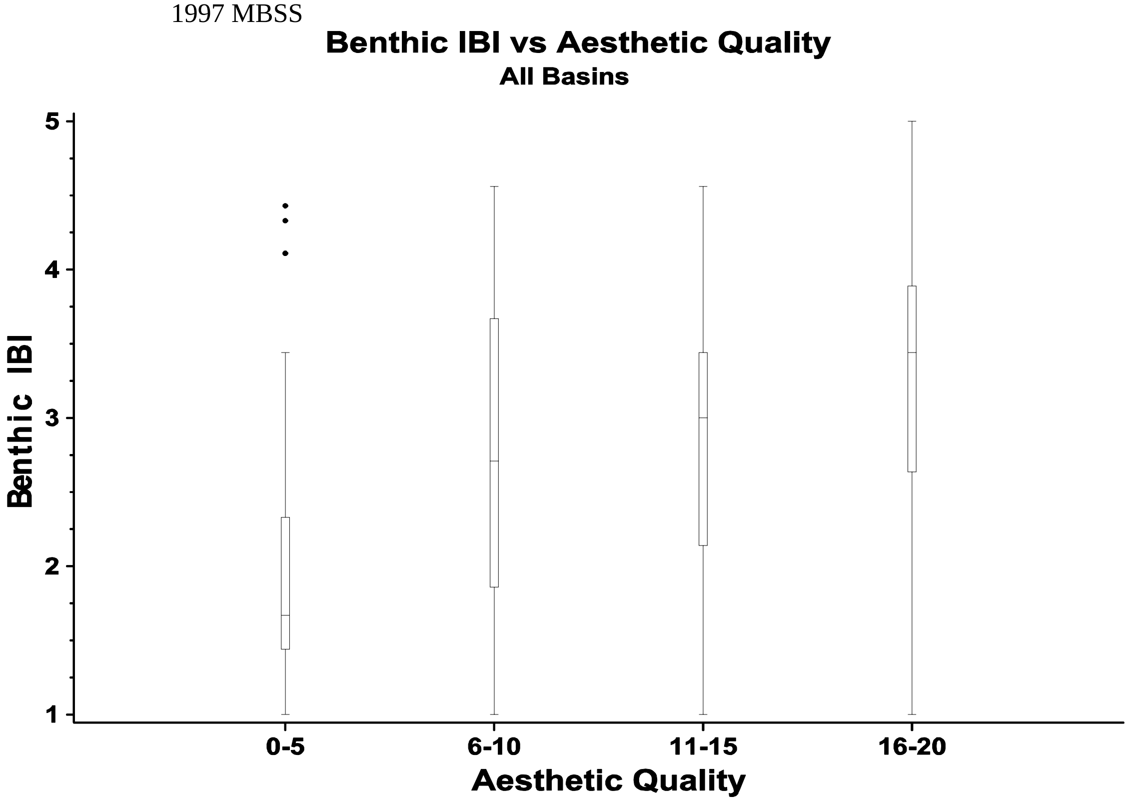


Figure 7-29. Relationship between the benthic IBI and aesthetic quality, statewide for the 1995-1997 MBSS

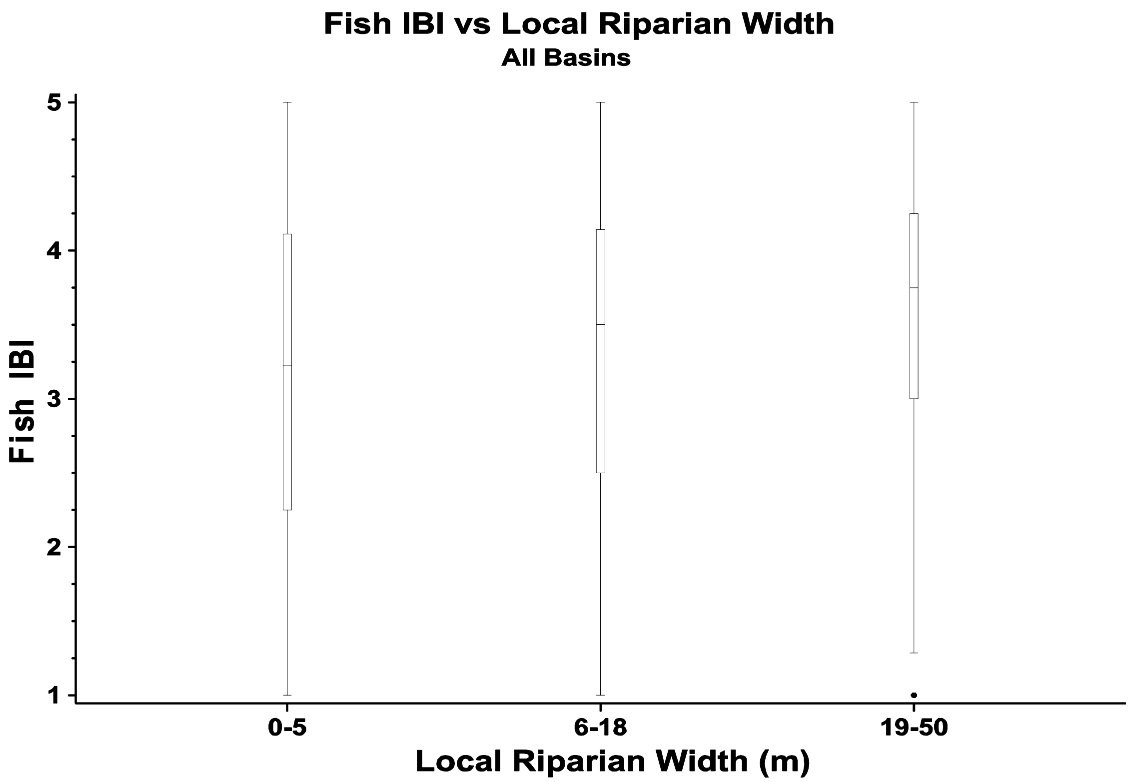


Figure 7-30. Relationship between the fish IBI and local riparian buffer width, statewide for the 1995-1997 MBSS

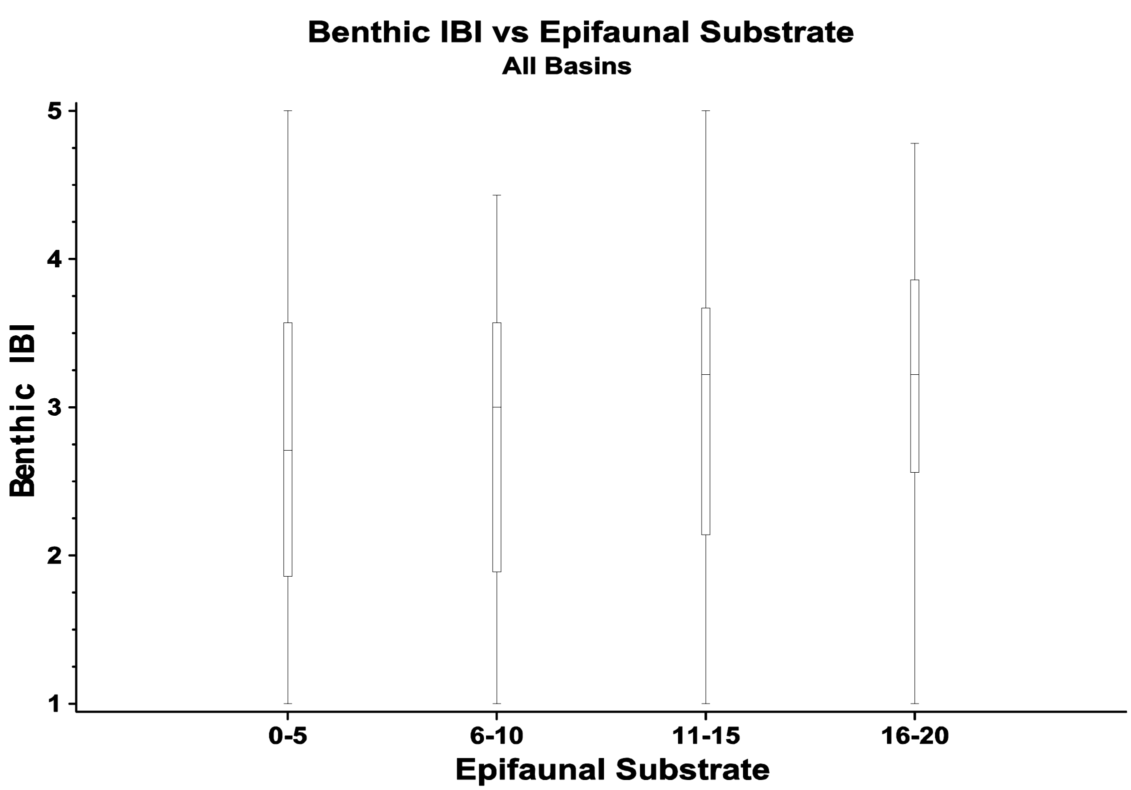


Figure 7-31. Relationship between the benthic IBI and epifaunal substrate, statewide for the 1995-1997 MBSS

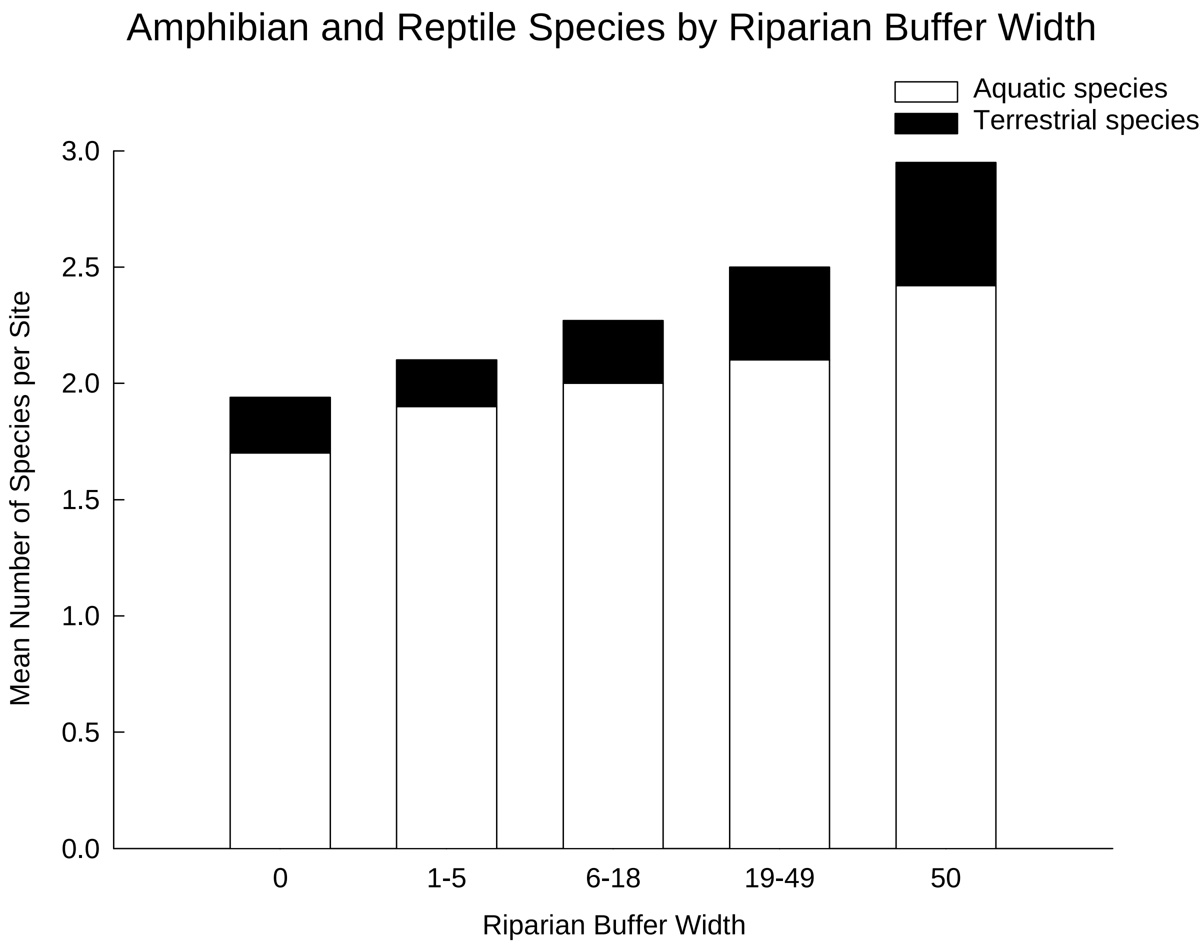


Figure 7-32. Mean number of amphibian and reptile species per site for each category of riparian buffer width, statewide, for the 1995-1997 MBSS

sites, while aquatic species were more common at grassy or wetland sites, although these differences were within the range of error of these estimates.

A stream's remoteness may influence species with particular ecological requirements or a need for undisturbed habitat. Also, remote sites are less accessible to anglers, which could affect gamefish populations. To test the influence of remoteness, brook trout densities were compared between remote and non-remote sites. Remote sites were defined as sites receiving an optimal remoteness score (at least 16 points out of 20). Statewide, brook trout density was estimated at 54 individuals per stream mile. Among remote sites, density was 138 brook trout per stream mile, compared with 36 individuals per stream mile at non-remote sites. In particular, brook trout density was higher at remote sites in the Gunpowder and Youghiogheny (1995 sampling), but not in other basins. The percentage of harvestable-sized brook trout (>6 inches total length) did not increase with remoteness, but the density of harvestable-sized brook trout did increase. Statewide, 17% of brook trout were of harvestable size. An estimated 15% of brook trout in remote streams were of harvestable size, compared with 19% at non-remote sites. A notable exception was in the North Branch Potomac, the basin with the greatest overall percentage of harvestable-sized brook trout (35%). Within this basin, the percentage of harvestable brook trout was an impressive 66% at remote sites, compared with 26% in non-remote streams.

8 NUTRIENTS

This section presents water quality results related to nutrient and dissolved oxygen concentrations from the 1995-1997 Maryland Biological Stream Survey (MBSS, or the Survey). Levels of nitrate-nitrogen (NO_3-N) and dissolved oxygen (DO) are examined for streams in each of the basins sampled in the Survey. To assess the comparability of the spatially diverse MBSS data with a less extensive but longer-term data set, results are compared with the nutrient data obtained from DNR's CORE/Trend monitoring stations located throughout the State.

8.1 BACKGROUND INFORMATION ON NUTRIENTS

Nutrients such as nitrogen are important for life in all aquatic systems. In the absence of human influence, streams contain a background level of nitrogen that is essential to the survival of the aquatic plants and animals in that system. However, during the last several hundred years, the amount of nitrogen in many stream systems has increased, as a result of anthropogenic influences such as agricultural runoff, wastewater discharge, and urban/suburban nonpoint sources.

Elevated nitrogen concentrations are one contributor to nutrient enrichment in aquatic systems. Excessive nitrogen loading may lead to the eutrophication of the water body, particularly in downstream estuaries. Eutrophication often decreases the level of dissolved oxygen available to aquatic organisms. Prolonged exposure to low dissolved oxygen values can suffocate adult fish or lead to reduced recruitment. Increased nutrient loads are also thought to be harmful to humans by causing toxic algal blooms and contributing to outbreaks of toxic organisms such as *Pfiesteria piscicida.*

In Maryland, concern for nutrient loadings to the Chesapeake Bay has drawn attention to the amounts of materials transported from throughout the watershed by stream tributaries. In the Chesapeake Bay watershed, the largest source of nitrogen is from agriculture (estimated as 39% of total nitrogen). Other contributors include point sources (23%), runoff from developed areas (9%) and forests (18%), and direct atmospheric deposition to the Bay surface (11%). The total contribution of atmospheric deposition is higher (27%), including amounts deposited to the watershed and subsequently entering the Bay as runoff (Chesapeake Bay Program 1995). Atmospheric deposition is therefore recognized as a significant contributor of nitrogen to the Bay, including deposition reaching the watershed from power plants and other distant sources (Dennis 1996).

The Survey provides a large dataset that can be used to assess nutrient concentrations under spring baseflow conditions. Although a full understanding of nutrient loadings also requires data collected over time (i.e., taken over multiple years and seasons), the Survey's water chemistry results provide extensive spatial coverage (with nearly 1,000 sites sampled) that enables nitrogen concentrations to be compared among basins statewide. Maryland's CORE/Trend monitoring program provides information regarding long-term water chemistry conditions, as described briefly below.

The Survey measures concentrations of NO_3-N, one of the most common forms of nitrogen found in aquatic systems. For the analysis of MBSS data, concentrations were broken down into the following categories: NO_3-N > 7 mg/l (the most highly elevated concentrations observed), > 3.0 mg/l (moderately elevated), >1.0 mg/l (slightly elevated, considered indicative of anthropogenic influence), 0.01-1.0 mg/l, and <0.01 mg/l. The mean instream concentration of NO_3-N was examined statewide and for each individual basin. Dissolved oxygen concentrations, which may be affected by NO_3-N concentrations, were broken down into the following categories: DO < 3 ppm, 3-5 ppm, and > 5 ppm.

8.2 RESULTS OF NUTRIENT ASSESSMENT

Statewide, the majority of stream miles (59%) had NO_3-N concentrations greater than 1.0 mg/l. An estimated 41% of stream miles had NO_3-N concentrations between 0.1 mg/l and 1.0 mg/l, and only 0.4% had concentrations that were less than 0.1 mg/l. Only three basins had any stream miles (< 5%) with less than 0.1 mg/l of NO_3-N: the Upper Potomac, the Lower Potomac, and the West Chesapeake. An estimated 29% of stream miles had a NO_3-N concentration greater than 3.0 mg/l and an estimated 5% of stream miles had a NO_3-N concentration greater than 7.0 mg/l. Areas where the concentration is greater than 7.0 mg/l are places where NO_3-N may be especially detrimental to stream quality. These areas occurred in seven of the basins sampled: Upper Potomac, Middle Potomac, Lower Potomac, Patuxent, Patapsco (1995 and 1997 sampling), Susquehanna, Elk, Chester, Choptank (1996 and 1997 sample years), and Nanticoke/Wicomico basins. Figure 8-1 shows the percentage of stream miles by basin where NO_3-N concentrations were greater than 1.0 mg/l and that which is greater than 7.0 mg/l.

The mean statewide NO_3-N concentration was 2.45 mg/l. First-order streams had a slightly higher mean NO_3-N concentration (2.56 mg/l) than either second (2.21) or third-order (2.15) streams. Eight basins had average NO_3-N concentrations greater than the statewide average: the Middle Potomac, Patapsco (1995 and 1996 sampling), Gunpowder, Susquehanna, Elk, Chester, Choptank (1996 and 1997 sampling), and Nanticoke/Wicomico basins. For the most part, these are the same basins that had sites with NO_3-N concentrations greater than 7.0 mg/l. The distribution of the mean NO_3-N concentration by basin is shown in Figure 8-2.

Organisms unable to tolerate polluted conditions may be reduced or eliminated in streams with elevated nutrient concentrations. For example, numbers of benthic Ephemeroptera, Plecoptera, and Trichoptera (EPT), taxa generally sensitive to degradation, were diminished in streams with higher NO_3-N concentrations (Figure 8-3).

The Hilsenhoff Biotic Index is a useful measure of the intolerance of benthic macroinvertebrates to organic pollution (Hilsenhoff 1977, 1987, 1988; Klemm et al. 1990; Plafkin et al. 1989). It is expected that the Index would be high (indicating greater prevalence of tolerant taxa) where instream concentrations of NO_3-N are high. Statewide, the Hilsenhoff Biotic Index and NO_3-N concentration were significantly related (linear regression, $p<0.0001$, $r^2=0.03$; Figure 8-4), but there was a great deal of variation when all sample sites were pooled.

In some aquatic systems, low dissolved oxygen levels may result from nitrogen inputs. Statewide, the majority of stream miles contained dissolved oxygen concentrations that were greater than 5.0 ppm (94%), a level generally considered healthy for aquatic life. An estimated 3% of stream miles had dissolved oxygen concentrations that fell between 3.0 ppm and 5.0 ppm, while 3% had concentrations less than 3.0 ppm. Seven basins had stream miles with a dissolved oxygen concentration less than 3.0 ppm: the Upper Potomac, Lower Potomac, Patuxent, West Chesapeake, Patapsco (1996 sampling), Chester, and Pocomoke basins (Figure 8-5). This result suggests that high NO_3-N levels are ameliorated by reaeration and other factors. Seasonal monitoring of streams suspected to have low DO problems and examination of watershed factors would help to diagnose situations where the problem is persistent and can be linked to anthropogenic causes.

8.3 COMPARISON WITH CORE/TREND MONITORING DATA

Maryland DNR's CORE/Trend program, begun in 1974, is part of the State of Maryland's long-term ambient monitoring of stream water quality. Surface water samples are collected monthly at 55 stations located throughout the State and analyzed for a variety of physiochemical parameters. In addition, benthic macroinvertebrates are sampled annually at 27 of these stations. Stations from the CORE/Trend program are located in 11 of the 17 basins in the State: the Youghiogheny, North Branch Potomac, Upper Potomac, Middle Potomac, Potomac Washington Metro, Patuxent, Patapsco, Gunpowder, Susquehanna, Chester, and Choptank.

To compare CORE/Trend data with MBSS results, NO_3-N values from the CORE/Trend stations were examined for April and May of 1995, 1996, and 1997. For each station, the mean for these two months was calculated by year (Figure 8-6). These data, averaged across the three years, were compared to the mean NO_3-N results from the MBSS (Figure 8-7).

Overall, the statewide average NO_3-N concentration from the CORE/Trend data was 1.82 mg/l, while the average statewide NO_3-N concentration from the MBSS data was 2.45 mg/l. Average NO_3-N concentrations in the Youghiogheny and the North Branch Potomac basins were both consistently low, showing very little difference between monitoring programs. In the Upper Potomac and Patuxent basins, the average NO_3-N concentration was higher at the CORE/Trend stations than at the MBSS sites. In the remaining basins that were sampled in both programs, the NO_3-N concentration was higher at the MBSS sample sites than at the CORE/Trend stations. The greatest difference was in the Choptank basin where MBSS data sets had an average NO_3-N concentration of 4.13 mg/l, while the CORE/Trend data had an average concentration of 1.32 mg/l. Differences in values within individual basins are, in part, explained by differences in sample site locations. MBSS sites do not necessarily occur in the same parts of the basin sampled by the CORE/Trend program, and some CORE/Trend sites may be influenced by conditions outside of areas sampled by MBSS. For example, CORE/Trend sites on the mainstem Potomac River may be affected by farming activity in West Virginia or Virginia.

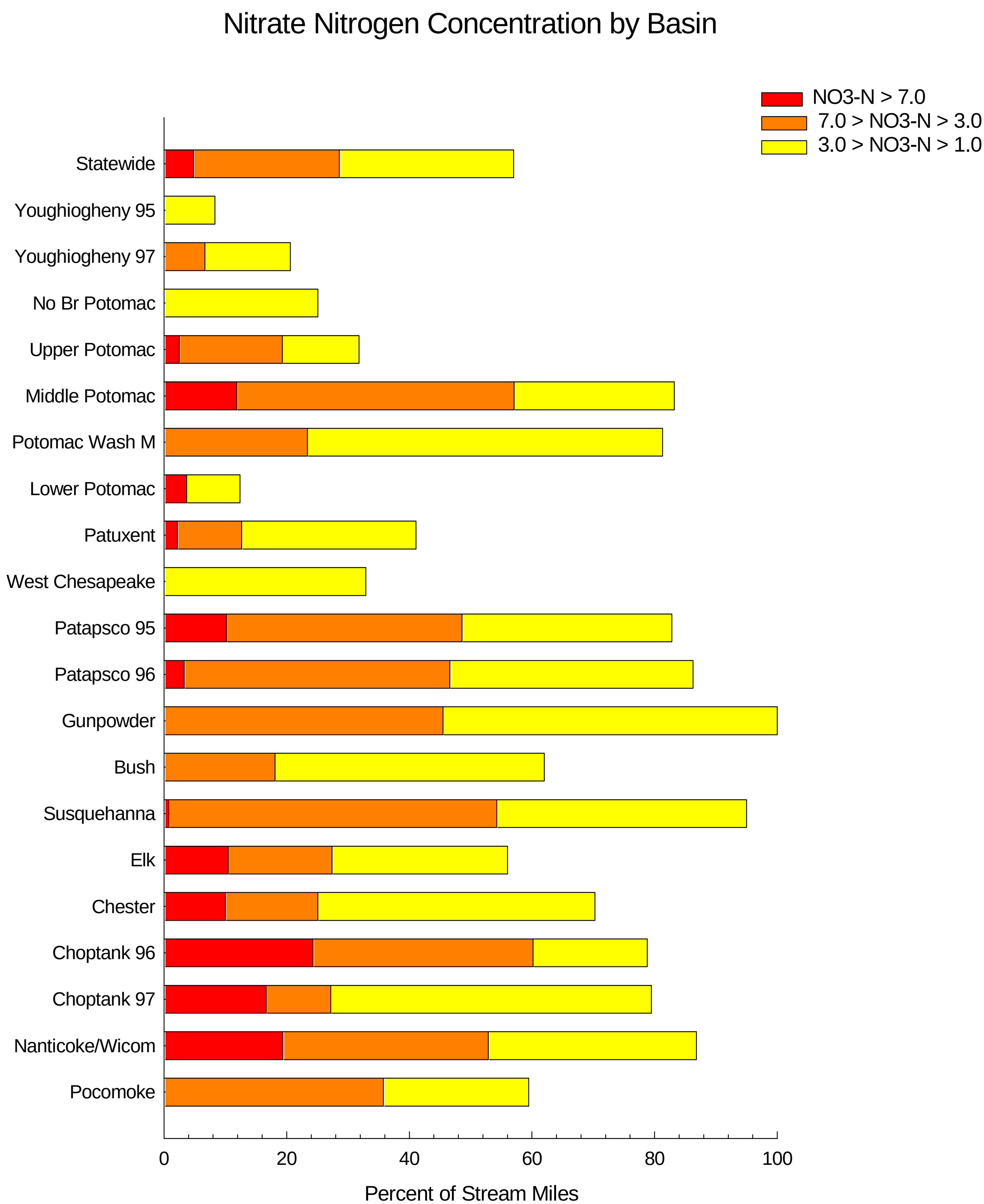


Figure 8-1. Nitrate nitrogen (NO_3-N) concentration (mg/l) statewide and for basins sampled in the 1995-1997 MBSS. Categories shown are: NO_3-N > 7.0 mg/l, 7.0 mg/l > NO_3-N > 3.0 mg/l and 3.0 mg/l > NO_3-N > 1.0 mg/l.

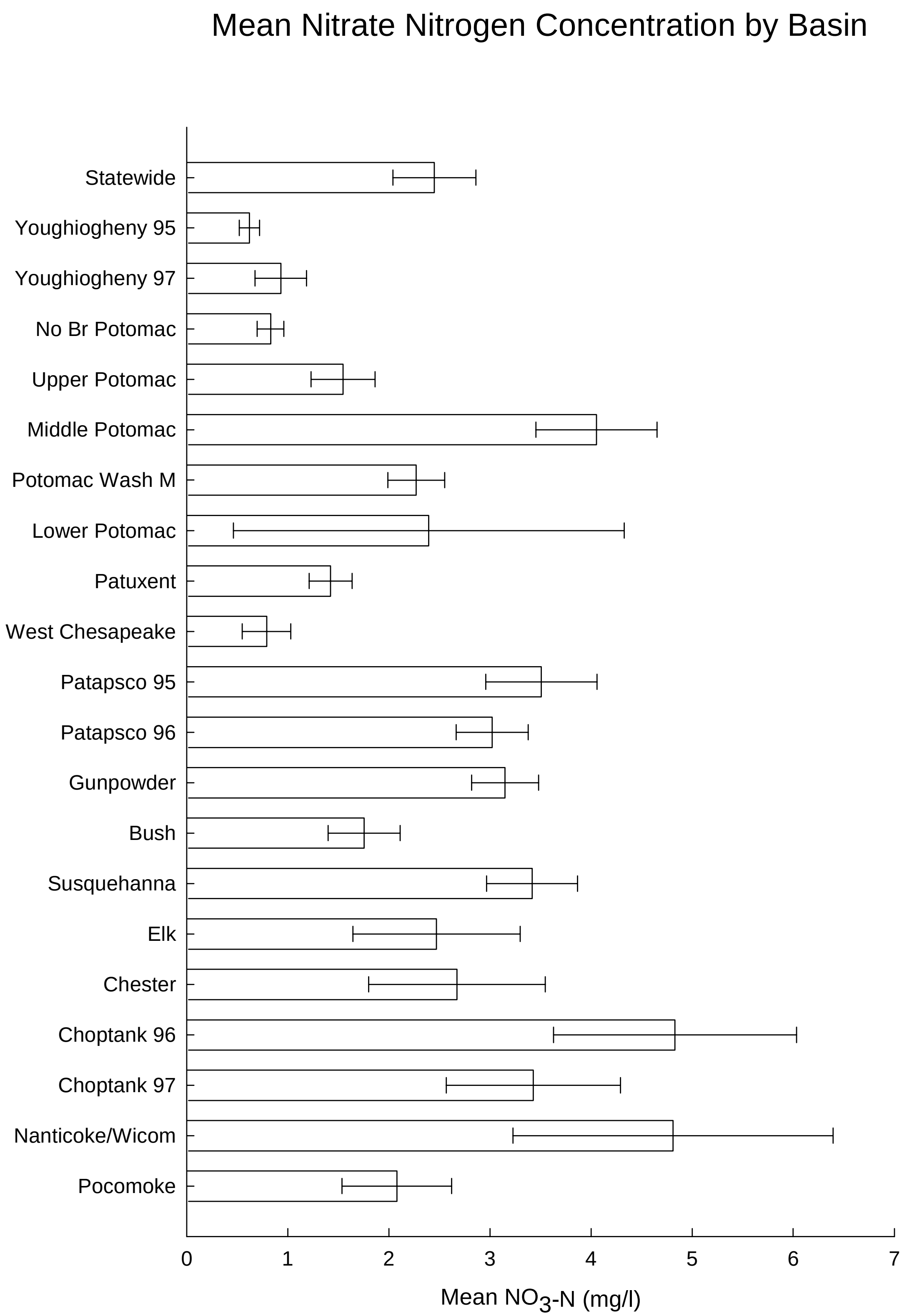


Figure 8-2. Mean nitrate nitrogen (NO_3-N) concentration (mg/l) statewide and for basins sampled in the 1995-1997 MBSS. Error bars indicate ±1 standard error.

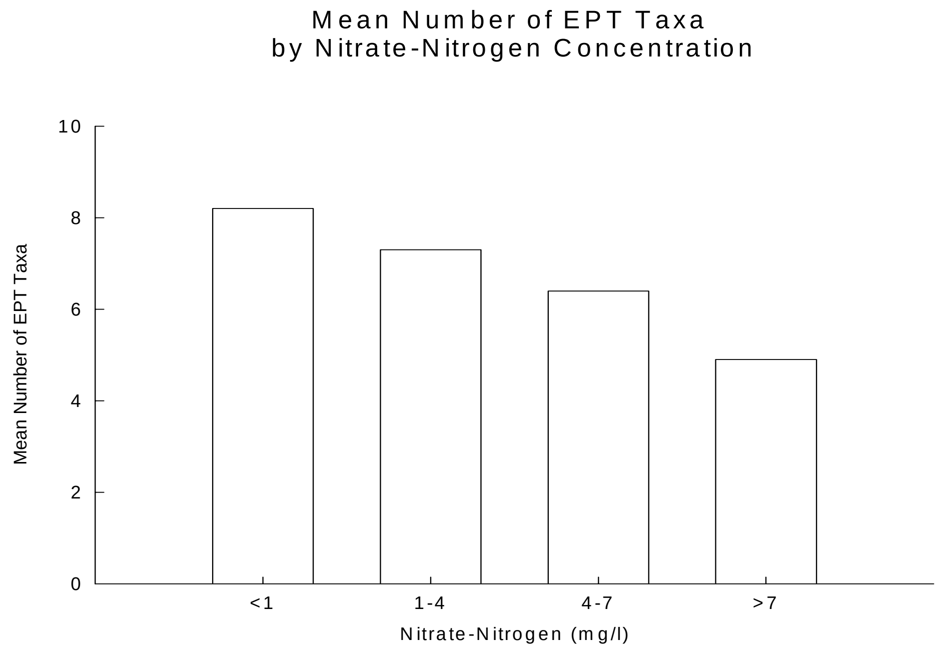


Figure 8-3. Mean number of benthic Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa declined with higher nitrate nitrogen concentration at 1995-1997 MBSS sites

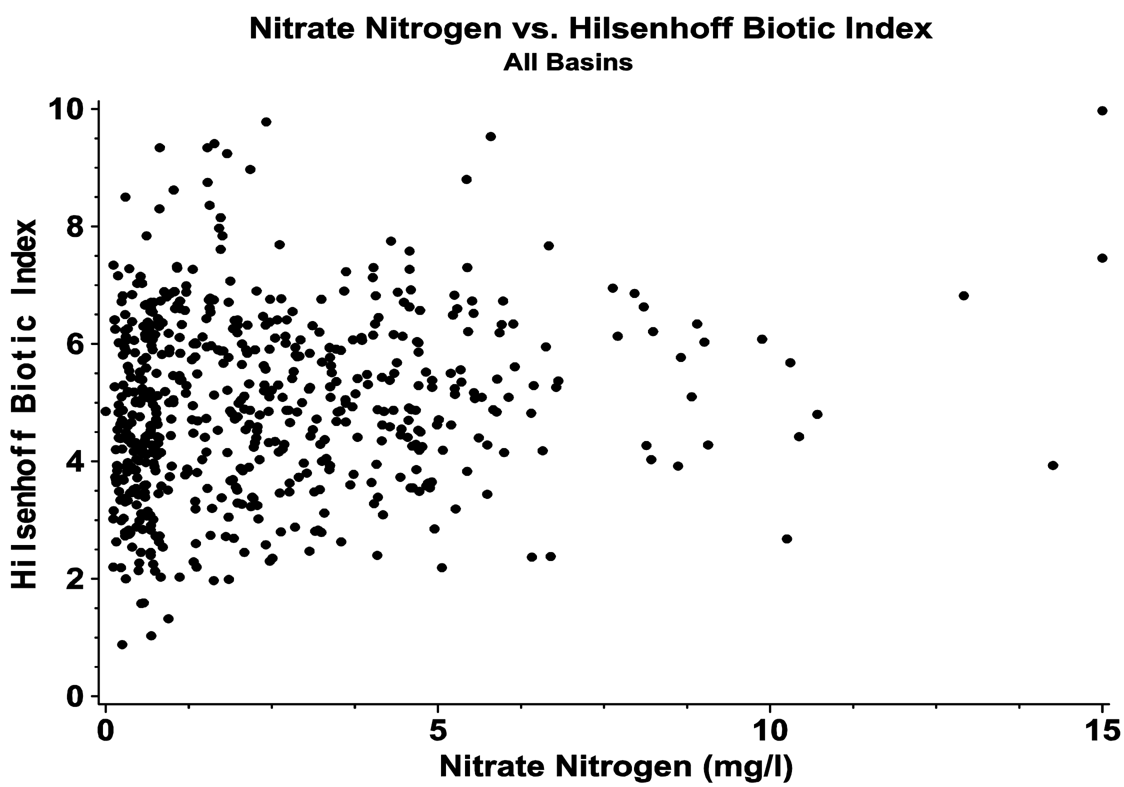


Figure 8-4. Relationship between nitrate nitrogen (NO_3-N) concentration (mg/l) and the Hilsenhoff Biotic Index for the 1995-1997 MBSS ($p<0.0001$, $r^2=0.03$)

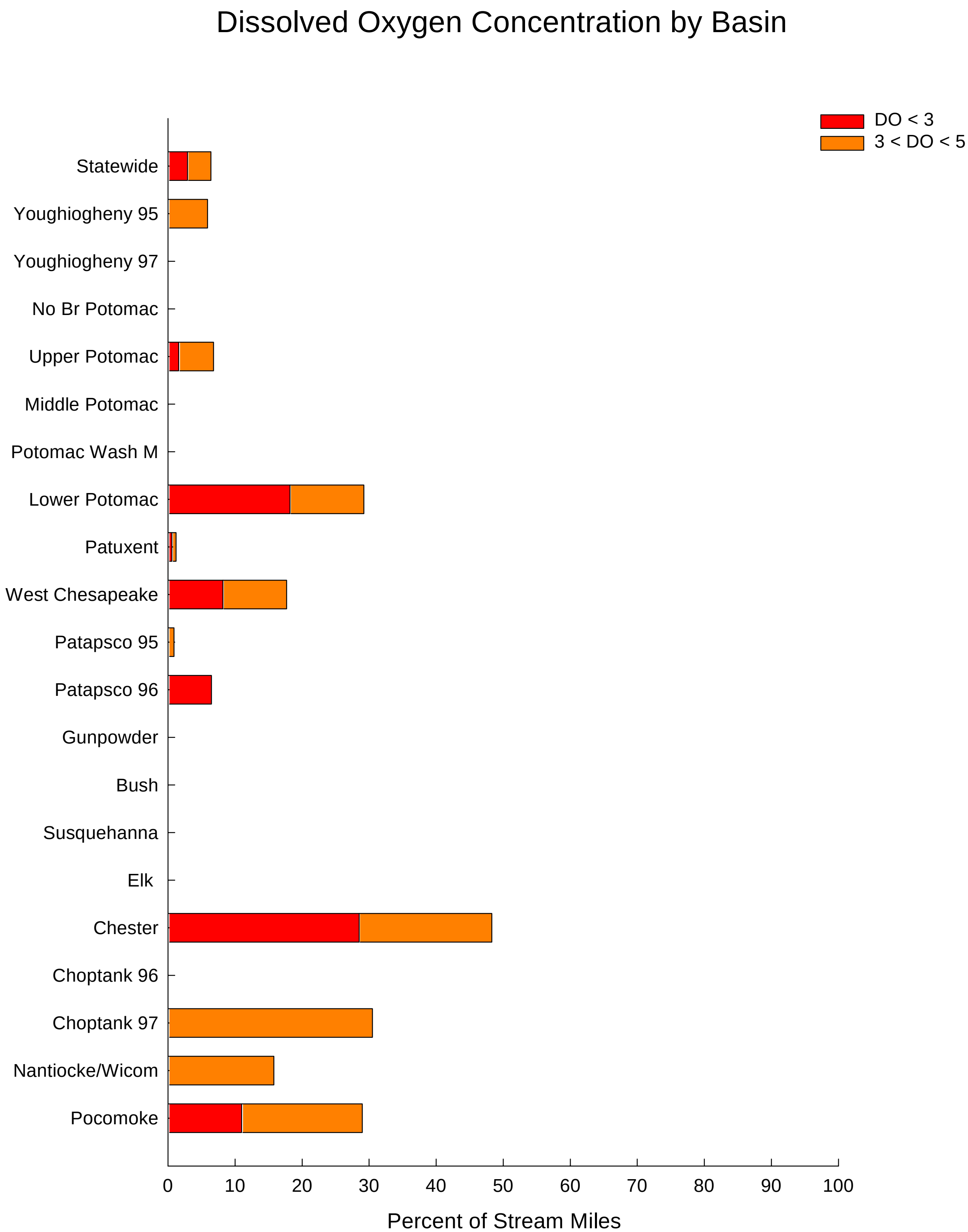


Figure 8-5. Dissolved oxygen (DO) concentration (ppm) statewide and for basins sampled in the 1995-1997 MBSS. Categories shown are: DO < 3 ppm and 3 ppm < DO < 5 ppm.

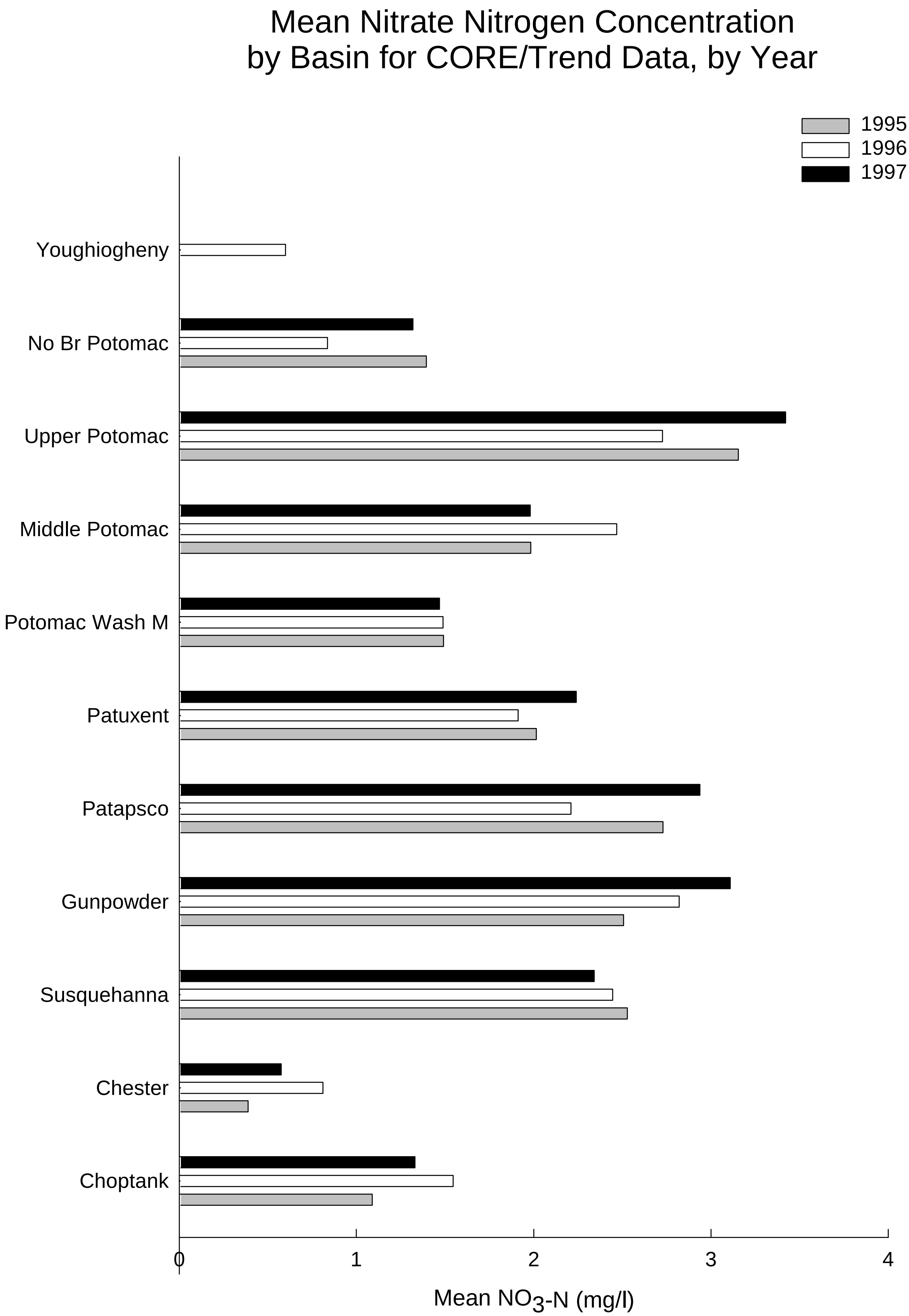


Figure 8-6. Mean nitrate nitrogen (NO_3-N) concentration (mg/l) for CORE/Trend stations sampled in April and May of 1995, 1996, and 1997

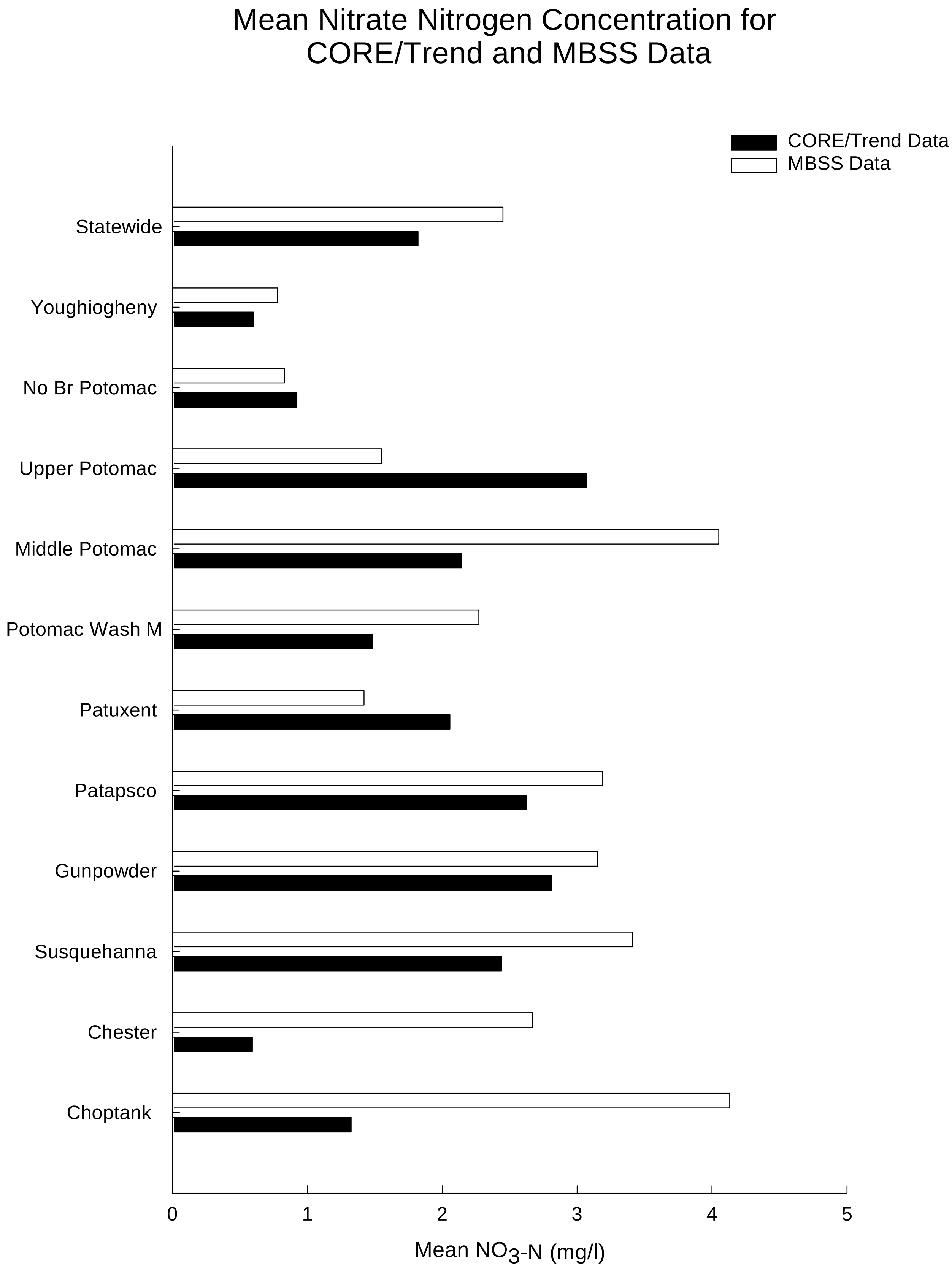


Figure 8-7. Mean nitrate nitrogen (NO_3-N) concentration (mg/l) for CORE/Trend stations sampled in April and May of 1995-1997 and for MBSS sites sampled during the spring index period of 1995-1997.

To examine whether data from the two programs tend to rank basins in a similar order, a Spearman rank correlation of NO_3-N concentrations was conducted. Three basins were excluded from the analysis due to obvious differences in areas covered by sampled locations. The CORE/Trend station in the Susquehanna basin is located in the mainstem river and therefore is likely to be influenced by Pennsylvania streams. Similarly, CORE/Trend stations in the Upper Potomac and Potomac Washington Metro basins located on the mainstem Potomac may not reflect the same conditions affecting MBSS stream sites within these basins. Remaining basins were ranked according to NO_3-N concentrations for each program. Ranks were then tested for correlation. This result was not significant ($p=0.31$), indicating that basin NO_3-N concentrations are ranked differently by the two monitoring programs.

There are several reasons for the differences in NO_3-N results between the two programs. The first is that the programs sampled at different locations within a basin. Therefore, differences in surrounding land use or even in natural water chemistry may be reflected in average NO_3-N concentrations. Differences in time of sample collections may also contribute to this variation. For instance, a sample for one program may have been taken after a rainstorm, when NO_3-N from runoff was present in higher concentration. Finally, the majority of CORE/Trend sites are located in fourth-order and larger streams, while the MBSS sites are restricted to third-order and smaller streams that may be more strongly influenced by direct watershed inputs. In larger streams, a similar rate of NO_3-N influx could be diluted by greater streamflow, resulting in lower instream concentrations. In fact, MBSS results showing slightly higher NO_3-N concentrations in first-order streams are consistent with this hypothesis. Furthermore, results of other surveys indicate that probability-based surveys such as the MBSS generally capture more disturbed sites than do fixed-site surveys. In future analysis, a more in-depth comparison could be done using specific MBSS sites located upstream of CORE/Trend stations, to examine geographic patterns in nutrient concentrations between small tributaries and corresponding downstream CORE/Trend streams, which integrate nutrient inputs over a larger watershed area.

9 WATERSHED LAND USE

Stream conditions are often influenced by human activities in the surrounding watershed. Historically, much of Maryland was covered by forest, a sharp contrast to the variety of urban and agricultural uses presently dominating the landscape (Figure 3-5). Current stream conditions are in part determined by these human uses of watershed lands. Results in this chapter describe the range of land uses in watersheds upstream of sites sampled in the Maryland Biological Stream Survey (MBSS, or Survey) and explore the associations between land use and stream conditions, using biological and physical habitat indicators.

9.1 BACKGROUND

Human activities affect streams at a variety of spatial scales. Rivers are by nature hierarchical systems, so the character of a local stream site is to some degree controlled by the larger-scale river system and watershed to which it belongs. This means that to fully understand the multiple, cumulative impacts on stream systems, conditions at a broad landscape scale, as well as the local or site-specific scale, must be assessed. For example, while water chemistry results may indicate that acidic deposition is the likely cause of degraded fish communities at a particular site, there may be other stresses on that stream that would continue to inhibit fish or other stream biota even if the acidification was ameliorated. Urban development and the clearing of riparian vegetation upstream of the site may also be causing hydrological changes that accelerate bank erosion and sedimentation. In other cases, refugia within a local stream network may mitigate severe episodic stresses. This illustrates the need to include landscape-level information in the ecological assessment process. Only by using an integrated multiple-scale approach can the Survey provide context for evaluating the relative contributions of different anthropogenic activities.

One measure of anthropogenic influence at the landscape scale is watershed land use. Watersheds form natural geographic units for assessing impacts on streams, because land use within the watershed (or catchment) upstream of a specific stream site is representative of many of the human activities affecting the stream at that point. As such, land cover serves as a surrogate for a variety of stressors, some of which may be difficult to measure directly.

Because no field sampling program will ever be able to visit all sites or all streams through the state, the "wall-to-wall" coverage provided by land cover data serves as a useful tool for predicting conditions at sites that might otherwise be overlooked. Geographic information system (GIS) data may be used to develop predictive models linking land cover with instream biological or physical habitat conditions. In evaluating streams across a large area, GIS land cover information can be employed in an initial screening step to locate areas most likely to exhibit desirable or degraded conditions and to then target subsequent field sampling to these streams. Depending on management goals, these more detailed investigations would provide information needed to make decisions about appropriate conservation or restoration actions.

In much of the United States, conversions of naturally vegetated watershed lands to urban and agricultural uses have resulted in serious impacts to streams and their aquatic inhabitants. Examining land uses as stressors, through analyses of relationships with ecological indicators, allows predictions to be made about the extent and severity of ecological impacts associated with varying levels of human use. Some investigations have indicated that development of even small portions of a watershed may affect stream biota. For example, impervious surface covering 10-20% of the watershed area can have detrimental effects on streams (Schueler 1994). Impervious surfaces, such as roads, parking lots, sidewalks, and rooftops, cause a rapid increase in the rate at which water is transported from the watershed to its stream channels. Effects include more variable stream flows, increased erosion from runoff, habitat degradation caused by channel instability, increased nonpoint source pollutant loading, elevated temperatures, and losses of biological biodiversity.

Reviews of stream research in numerous watersheds (Center for Watershed Protection 1998, Schueler 1994) indicate that impacts on stream quality are commonly noted at about 10% coverage by impervious surface. Effects on sensitive species may occur at even lower levels (see brook trout example in Section 4). With even more impervious surface, most notably at about 25-30% of catchment area, studies have shown that numerous aspects of stream quality become degraded, including biological integrity, water quality, and physical habitat quality (Center for Watershed Protection 1998).

In this section, we examine urban land use, which represents impervious surface and other aspects of urbanization that affect stream quality. Note that the percent coverage by impervious surface for a catchment would be lower than the corresponding value for percent urban land assessed by the Survey. According to the class definitions used in developing the land cover base data (MRLC 1996 a,b), impervious surfaces make up 30-80% of the low-intensity and 80-100% of high-intensity developed urban land classes. Other land cover classes contribute smaller but possibly significant proportions of impervious surface. Therefore, the values for percent urban land use associated with poor stream quality were expected to be somewhat higher than the 10-30% impervious surface threshold reported by others.

Associations between urban or agricultural watershed land use and stream biota have been examined in a number of studies (e.g., Klein 1979, Steedman 1988, Richards et al. 1996, Roth et al. 1996). In this chapter, we report on the relationships observed between land use and several indicators of stream condition for sites sampled in the 1995-1997 MBSS. Ecological indicators included the fish Index of Biotic Integrity (IBI), benthic macroinvertebrate IBI and Hilsenhoff Biotic Index, number of aquatic salamander species, and Physical Habitat Index (PHI). Because the Survey employs a probability-based design, examining land use associations for the sampled sites allows us to make inferences about the effects of land use on biological resources statewide and within individual basins.

9.2 CHARACTERIZATION OF LAND USE IN UPSTREAM CATCHMENTS

A characterization of catchment land use was developed for the watershed upstream of each site sampled in the 1995-1997 MBSS using the GIS methods described in Chapter 2. Statewide, the dominant land use in site-specific catchments was forest (mean percent cover of 46%), followed by agriculture (44%) and urban (9%). In individual basins (Figure 9-1), agricultural land use was greatest at sites in the Susquehanna basin, with a per-site mean of 66%. Agriculture also dominated in the Middle Potomac, Gunpowder, and Elk basins, all with a per-site average of 63%. Sites in the North Branch Potomac had a mean of just 15%, while the mean in the remaining basins ranged from 22 to 60% agricultural land. Forest cover was most extensive for sites in the North Branch Potomac basin (83%) and least extensive in the Patapsco basin (1996 sampling, 21%). As expected, urban land use was greatest in the Patapsco (1996 sampling, 31%) and Potomac Washington Metro (23%) basins. Four of the remaining basins: the Patuxent, West Chesapeake, Patapsco (1995 sampling), and Bush basins contained a mean percentage of urban land use between 15 and 20%. The remaining basins had a mean percentage of urban land use that was less than 10%.

9.3 EXAMPLES OF LAND USE EFFECTS ON STREAM WATER QUALITY

One way that urbanization can affect stream water quality is through changes in water temperature. Stream water temperature is greater and more variable in streams draining urban lands than in streams draining forest lands. During summer, rain running off of hot impervious surfaces (parking lots, rooftops, etc.) and directly into streams causes temperature spikes during storms. Also, urban watersheds are likely to be less shaded than more natural forested watersheds. Where impervious surface is extensive, reduced infiltration may result in reduced groundwater input to stream baseflow. All of these factors contribute to higher average water temperatures and larger spikes in urban watersheds relative to forested watersheds.

In the Patuxent basin, during 1997, water temperature was measured at all MBSS sites every 15 minutes by continuous temperature loggers from June 5 to September 15. Mean daily temperatures ranged from 17°C (63°F) to 23°C (73°F), with an overall mean of 20°C (68°F). The maximum temperature reached in any stream was 31°C (88°F). Thus no sites in the basin exceeded the State Use I Temperature Criterion of 32°C (90°F) (COMAR 1995).

Two streams in the Patuxent basin illustrate the differences in stream water temperature based on the percentage of urban land in the catchment. Dorsey Run and Midway Run are second-order Coastal Plain streams with similar widths and depths (at the sampling sites) but fairly different land uses (Figure 9-2). Dorsey Run's watershed is mostly forested (73%), with only 10% urban land. The remainder of its watershed (17%) is agricultural. Midway Run's watershed, however, is nearly evenly split between forest (32%), urban (37%), and agricultural (31%) land.

During July 1997, the water in Midway Run was warmer in the daytime (and cooler at night) than Dorsey Run (Figure 9-3). Also, the highest daytime temperatures were reached more quickly in Midway Run than in Dorsey Run. The comparison between these two watersheds demonstrates how the loss of natural land cover can negatively affect water quality and potentially impair aquatic life, even though no regulatory criteria are exceeded.

Another way land use affects stream water quality is illustrated by the relationship between agricultural land use and instream nitrate-nitrogen (NO_3-N) concentration.

MBSS sites were divided into two groups: those with catchments dominated by agricultural land uses (>50% agriculture) and those with catchments predominately in other land uses (<50% agriculture). Spring baseflow NO_3-N concentrations were compared between the two groups. Among sites with >50% agriculture, the statewide mean NO_3-N concentration was 4.0 mg/l, more than three times the mean NO_3-N concentration among sites with <50% agriculture (mean NO_3-N of 1.2 mg/l). Within nearly every individual basin, NO_3-N concentrations were substantially higher among sites with agriculture >50% (Figure 9-4).

9.4 ASSOCIATIONS BETWEEN LAND USE AND ECOLOGICAL INDICATORS

9.4.1 Associations Between Land Use and the Fish IBI

For sites sampled in the 1995-1997 MBSS, fish IBI scores were plotted against the percentage of catchment area in various land uses (e.g., urban, agricultural, forest). Linear regression analyses were conducted to evaluate the strength of associations between land use and biological condition.

For all basins combined, fish IBI scores decreased with increasing urban land use (Figure 9-5; $p < 0.001$, r^2=0.09). Nearly all sites with greater than 50% of the catchment in urban land use had IBI scores indicating poor to very poor conditions (i.e., IBI < 3.0). However, among sites with a lower percentage of urban land use, a wide range of IBI scores was observed, representing good to very poor conditions. This suggests that factors other than urbanization have a strong influence on biological condition at these sites. Fish IBI showed a significant negative correlation to increasing urban land use in two of the individual basins: the Potomac Washington Metro (Figure 9-6; r^2=0.24) and the Patapsco (Figure 9-7; r^2=0.63). Catchments in these two basins have the largest amount of urban land area (average land use of 31% and 23%, respectively). Statewide, they also account for many of the sites that contain more than 50% urban land. Many of the remaining basins have very few sites with more than 25% urban land. In fact, there are several basins that have no sites with more than 10% urban land. These sites probably fall below the level at which significant effects of urbanization could be detected at this scale of analysis. In these less urbanized basins, factors other than urbanization appear to more strongly influence the degradation of stream quality.

The associations between fish IBI and more specific urban land use categories paralleled the general fish IBI and urban land use relationship. For many sites, the majority of urban land was characterized by low-intensity development, including areas with a mixture of built structures and vegetation. This is common in suburban neighborhoods dominated by single-family housing. The intensity of low-intensity developed areas ranged from 0 to 87% of the watershed area for sampled sites. Overall, a smaller percentage of watershed areas were characterized by high-intensity development, including heavily built-up urban centers and large developments in suburban and rural areas. This category contains areas in which a significant land area is covered by concrete, asphalt, or other artificial materials, including apartment complexes, skyscrapers, shopping centers, factories, industrial complexes, airport runways, and interstate highways. The percentage of high-intensity developed areas ranged from 0 to 28% of the watershed area for sampled sites.

As with urban land use in general, fish IBI scores showed a significant decrease with low- intensity developed areas, both over all basins (Figure 9-8; $p < 0.001$, r^2=0.09) and within the Potomac Washington Metro (r^2=0.25) and Patapsco (r^2=0.63) basins. These two basins have the greatest number of sites with a high percentage of land (>25%) in low-intensity development. These results suggest that even less dense urbanization may have a significant effect on streams in certain areas. Fish IBI was also significantly correlated with high-intensity development over all basins ($p < 0.001$, r^2=0.08), even though there were few sites with greater than 25% of the catchment in high-intensity development.

For all basins combined, fish IBI scores showed a significant positive relationship with percentage of agricultural land, although there was a high degree of variability (Figure 9-9; $p < 0.001$, r^2=0.07). This relationship was also seen in six of the individual basins: the Potomac Washington Metro, West Chesapeake, Patapsco, Gunpowder, Chester, and Nanticoke/Wicomico (r^2=0.08-0.57). The Gunpowder basin effectively demonstrates this relationship between the percentage of agricultural land and the fish IBI (Figure 9-10; $p<0.002$, r^2=0.25). Several factors might explain why fish IBI scores increase with the percentage of agricultural land use. Foremost may be the fact that as the amount of agricultural land use in a given area increases, the amount of urban land cover (a factor likely to cause more pronounced stream degradation) will usually decrease. There are also many complex interactions between agricultural activities and responses in stream biota that may affect the fish IBI in different ways. For example, while agriculture may cause erosion and degrade fish habitat, runoff may contribute lime (which can neutralize acidic inputs) and nutrients (which can enhance stream productivity). In general, because agriculture is so pervasive throughout the state, it may be difficult to detect its effects within the range of impact assessed by the IBI.

To investigate differences in the effects of row crop agriculture and less intensive agricultural land use (such as hayfields and pastureland), the agricultural land use class was further subdivided into these two categories. As with agricultural land use in general, fish IBI scores increased with an increasing percentage of land use in both categories over all basins combined, with row crop agriculture showing a slightly stronger relationship with the fish IBI ($p < 0.001$, $r^2=0.10$). However, it was difficult to discriminate the effects of row crop agriculture from hay/pasture land because the two cover types tended to be correlated.

Forest land use, although often extensive, had no significant relationship to fish IBI scores statewide. One confounding factor was the impact of acid deposition and acid mine drainage on streams in forested watersheds. A number of sites with > 50% forest cover were affected by acid deposition and mine drainage, and many of these sites had fish IBIs lower than would be expected (Figure 9-11).

The percentage of catchment area as wetlands showed no significant relationship to fish IBI statewide. Wetlands effects may be particularly hard to detect, given that wetlands cover only a small percentage of land throughout the state. Among all sites sampled, wetlands made up only 0-5% of catchment land cover.

Sites with high fish IBI scores represent biological communities least affected by degradation and provide an additional basis for analyzing land use associations with stream condition. Sites with high fish IBI scores (i.e., those rated as good, IBI $\geq$ 4.0) were distributed throughout the state, as seen in the maps in Chapter 5. Generally, these streams were characterized by less urban development. Sites with IBI $\geq$ 4 had an average of 4% urban land use, compared with an average of 9% for all sites. This result emphasizes the large effect that urban development may have on stream water quality.

9.4.2 Associations Between Land Use and the Benthic Macroinvertebrate IBI

For sites sampled in the 1995-1997 MBSS, benthic IBI scores were plotted against the percentage of catchment area in various land uses (e.g., urban, agricultural, forest). Linear regression analyses were conducted to evaluate the strength of associations between land use and biological condition.

Statewide, benthic IBI scores decreased with increasing urban land use (Figure 9-12; $p < 0.001$, $r^2=0.17$). Nearly all sites with greater than 30% of the catchment in urban land use had benthic IBI scores indicating poor to very poor conditions (i.e., IBI < 3.0). This may suggest that the benthic IBI is more sensitive to an increase in urban land use than the fish IBI, which, on average, reached the threshold for poor condition at about 50% of urban land use. Benthic IBI scores were also negatively correlated with urban land use in six individual basins: the North Branch Potomac, Potomac Washington Metro, Lower Potomac, Patuxent, Patapsco, and Bush (r^2=0.10-0.44). The relationship of the benthic IBI to urban land use is shown for the Potomac Washington Metro basin (Figure 9-13; $r^2=0.44$) and for the Patuxent basin (Figure 9-14; $r^2=0.32$).

The relationship of benthic IBI to low-intensity development parallels that of urban land use in general, showing a significant decrease over all basins combined (Figure 9-15; $p < 0.001$, $r^2=0.16$). As with the fish IBI, these results show that even a small amount of development may drastically affect the quality of a stream. Benthic IBI was also significantly negatively correlated to high-intensity development over all basins sampled ($p < 0.001$, $r^2=0.15$), although very few sites contained a large amount of high-intensity development.

Statewide, benthic IBI scores were not significantly correlated with the percentage of land that is agricultural (Figure 9-16; $p<0.24$). This may indicate that the benthic IBI is a better indicator of degradation from urban land use than from agricultural land use. There are several reasons that the relationship of the benthic IBI to agricultural land use is not significant, including the confounding interactions with biota mentioned when discussing the fish IBI.

The relationship between benthic IBI scores and the percentage of the catchment as forested land was positive and significant statewide (Figure 9-17; $p < 0.001$, $r^2=0.06$). Sites affected by acid deposition and acid mine drainage, most having > 50% of the catchment as forest, resulted in some lower-than-expected benthic IBI scores. When these sites were excluded from analysis, the relationship was slightly stronger ($r^2=0.08$). Basins showing significant relationships between forest cover and benthic IBI scores were the Upper Potomac ($r^2=0.07$) and Patapsco ($r^2=0.06$). Because wetland areas made up such a small percentage of catchment land, there was no significant relationship between wetland land use and the benthic IBI ($p<0.74$).

9.4.3 Associations Between Land Use and the Hilsenhoff Biotic Index

The Hilsenhoff Biotic Index is a macroinvertebrate indicator of organic pollution tolerance (Hilsenhoff 1977, 1987, 1988). High scores are associated with pollution tolerant organisms and therefore with stream degradation. For sites sampled in the 1995-1997 MBSS, Hilsenhoff Biotic Index scores were plotted against the percentage of catchment area in various land uses, especially urban and agricultural. Linear regression analyses were conducted to evaluate the strength of associations between land use and biological condition.

Statewide, Hilsenhoff Biotic Index scores increased with increasing urban land use, indicating increased degradation with an increase in urban land (Figure 9-18; $p < 0.001$, $r^2=0.11$). This relationship was also significant in three of the basins: the Potomac Washington Metro, Patuxent, and Patapsco ($r^2=0.16$-0.35), with the strongest relationship in the Potomac Washington Metro basin (Figure 9-19). These three basins are the ones with the highest percentages of urban land.

As with urban land use in general, Hilsenhoff Biotic Index scores showed a significant increase with low-intensity developed areas, both over all basins (Figure 9-20; $p < 0.001$, $r^2=0.11$) and within the three basins mentioned above. This result again suggests that even a small amount of urbanization may have a significant effect on streams. Hilsenhoff Biotic Index scores were also significantly correlated with high-intensity development, increasing as development increased ($p < 0.001$, $r^2=0.11$).

Statewide, Hilsenhoff Biotic Index scores increased with increasing agricultural land use (Figure 9-21; $p < 0.001$, $r^2=0.02$). This result indicates an increase in degradation with an increased percentage of land in agricultural land use, unlike the results seen with the fish and benthic IBIs. It is likely that the Hilsenhoff Biotic Index is better able to detect organic pollution, a compelling reason for using it as an ancillary indicator to the IBIs. The positive relationship is also seen in six of the individual basins: the Youghiogheny, North Branch Potomac, Upper Potomac, Middle Potomac, West Chesapeake, and Gunpowder ($r^2=0.04$-0.24), with the North Branch Potomac having the strongest relationship.

Hilsenhoff Biotic Index scores were significantly correlated to the percentage of land in forest cover for all basins, decreasing with increasing forest cover (Figure 9-22; $p < 0.001$, $r^2=0.11$). This significant negative relationship was also noted in eight of the individual basins: the Youghiogheny, North Branch Potomac, Upper Potomac, Middle Potomac, West Chesapeake, Patapsco, Gunpowder, and Chester basins ($r^2=0.04$-0.22), with the strongest relationship in the Upper Potomac basin.

9.4.4 Associations Between Land Use and Aquatic Salamanders

In addition to the biological indices discussed above, other components of stream communities are significantly affected by land use. Some of these components may prove to be effective new indicators of land use effects; most often the utility of each indicator is dependent on the number and range of values for that indicator. In any case, considering a broader range of biological components can better address impacts on biodiversity.

One promising biological indicator is the number of aquatic salamanders found at each stream site. Although salamander abundance was not included in the results of the 1995-1997 MBSS, fairly reliable counts of aquatic salamander species were obtained. For sites sampled in the 1995-1997 MBSS, the number of aquatic salamander species were plotted against the percentage of catchment area in each land use. Linear regression analyses were conducted to evaluate the strength of associations between land use and biological condition. Although the number of aquatic salamanders per stream site never exceeded five, aquatic salamander richness was significantly correlated with the percentage of urban, agricultural, and forest land uses.

Statewide, the number of aquatic salamander species decreased with increasing urban land use, indicating a loss of biodiversity with more urban land (Figure 9-23; $p < 0.0001$, $r^2=0.03$). This relationship was also significant for aquatic salamander species richness in the Highlands ($p < 0.017$, $r^2=0.02$) and Piedmont ($p < 0.0002$, $r^2=0.04$) regions of Maryland. A similar negative relationship was observed between aquatic salamander species richness and increasing agricultural land use statewide ($p < 0.0038$, $r^2=0.01$) and in the Highlands ($p < 0.0001$, $r^2=0.05$). A significant positive relationship was evident in the Piedmont, likely reflecting the reciprocal relationship between agriculture and urban uses in that region. As expected, aquatic salamander species richness increased with increasing forested land use statewide ($p < 0.0001$, $r^2=0.05$) and in the Highlands ($p < 0.0001$, $r^2=0.07$). The relationship in the Piedmont was not significant.

Especially in small streams that often contain few or no fish species, aquatic salamanders appear to be an effective indicator of land use influences. Unlike fish, aquatic salamanders showed a negative association with agricultural land use statewide. Future monitoring efforts may improve this indicator by adding abundance measures and more thoroughly sampling for adult and larval salamanders.

9.4.5 Associations Between Land Use and the Physical Habitat Index

Although linkages between watershed land use and physical habitat conditions have been demonstrated in a number of studies, MBSS statewide results did not indicate declines in PHI scores with increased urban or agricultural land use. It is likely that the parameters included in the PHI do not represent all the aspects of habitat quality that can be affected by human alterations to watershed lands. Further examination of individual habitat factors might reveal stronger associations with catchment land use.

Within several individual basins, some associations between land use and the PHI were detected. In the Potomac Washington Metro basin, agricultural land use had a significant negative relationship with PHI ($p=0.002$, $r^2=0.14$). Forest land cover had a significant positive relationship with PHI in the Potomac Washington Metro ($p=0.01$, $r^2=0.09$) and Bush ($p=0.03$, $r^2=0.26$) basins.

The lack of correspondence between land use and PHI is not unexpected, given the scale of analysis. Certainly, some processes that affect physical habitat do operate on a watershed level: for example, sediment transport may increase embeddedness and flow variability leads to channel instability and degradation of naturally-occurring riffles and pools. However, other components of physical habitat are affected or assessed at a more local scale. The amount of instream woody debris at a particular site depends on the availability of nearby tree cover. Maximum depth depends on watershed size and local variation in geography, although in some cases major flow fluctuations can result in development of shallow, overwidened channels. Aesthetic quality is assessed at a local level, based on streamside field observations. Thus a stream in a forested park, within an otherwise developed watershed, may still rate high in aesthetic quality. Clearly, numerous aspects of physical habitat quality are affected by land use, although not always in ways detected by our GIS-based estimates.

9.5 IMPLICATIONS

In general, biological indicators did show a number of significant relationships to catchment land uses. Fish and benthic IBI scores were particularly sensitive to the degree of watershed urbanization, but were less able to detect effects of agriculture at the watershed scale. Benthic IBI scores increased with the amount of forest cover. The Hilsenhoff Biotic Index was able to detect degradation associated with both urban and agricultural lands, and was also related to forest cover. In many cases, examining relationships within individual basins provided a clearer picture of land use relationships than did statewide results.

Urbanization and agriculture have historically exerted and will continue to exert significant pressure on stream ecosystems in Maryland. Currently, three basins (Patapsco, Potomac Washington Metro, and West Chesapeake) contain the majority of sampled sites with greater than 25% urban land in the upstream catchment. However, as human population continues to grow, development pressure (and with it, the percentage of urban land) will likely extend to other parts of the state. Recent statewide efforts to improve land use planning and requirements for stormwater management may lessen the negative impacts of urban and suburban development. Programs aimed at reducing point and nonpoint nutrient loadings to the Chesapeake Bay (such as Maryland's Tributary Strategies, riparian reforestation, and management of crop nutrients and animal waste) will likely benefit streams as well.

While this analysis represents significant progress in understanding the ecological effects of urbanization and agriculture at the statewide and river basin scales, additional studies will likely provide further insights. The extent of agricultural influence does not take into account variations in land slope, soil erodibility, or implementation of Best Management Practices that may exacerbate or ameliorate adverse effects at individual sites. Similarly, urban impacts may vary, depending on the amount of impervious surface and the nature of point sources discharging to streams. Perhaps most importantly, the composition of riparian (streamside) land cover is critical to understanding the influence of land use and to target conservation measures (such as reforestation) that can improve stream conditions. Related studies are now underway to compare the influences of riparian and catchment conditions, using MBSS data for the Patapsco and other basins. Other efforts are continuing to improve on existing predictive models by incorporating other indicators of landscape condition (e.g., impervious surface), as well as other stressors (see Chapter 11).

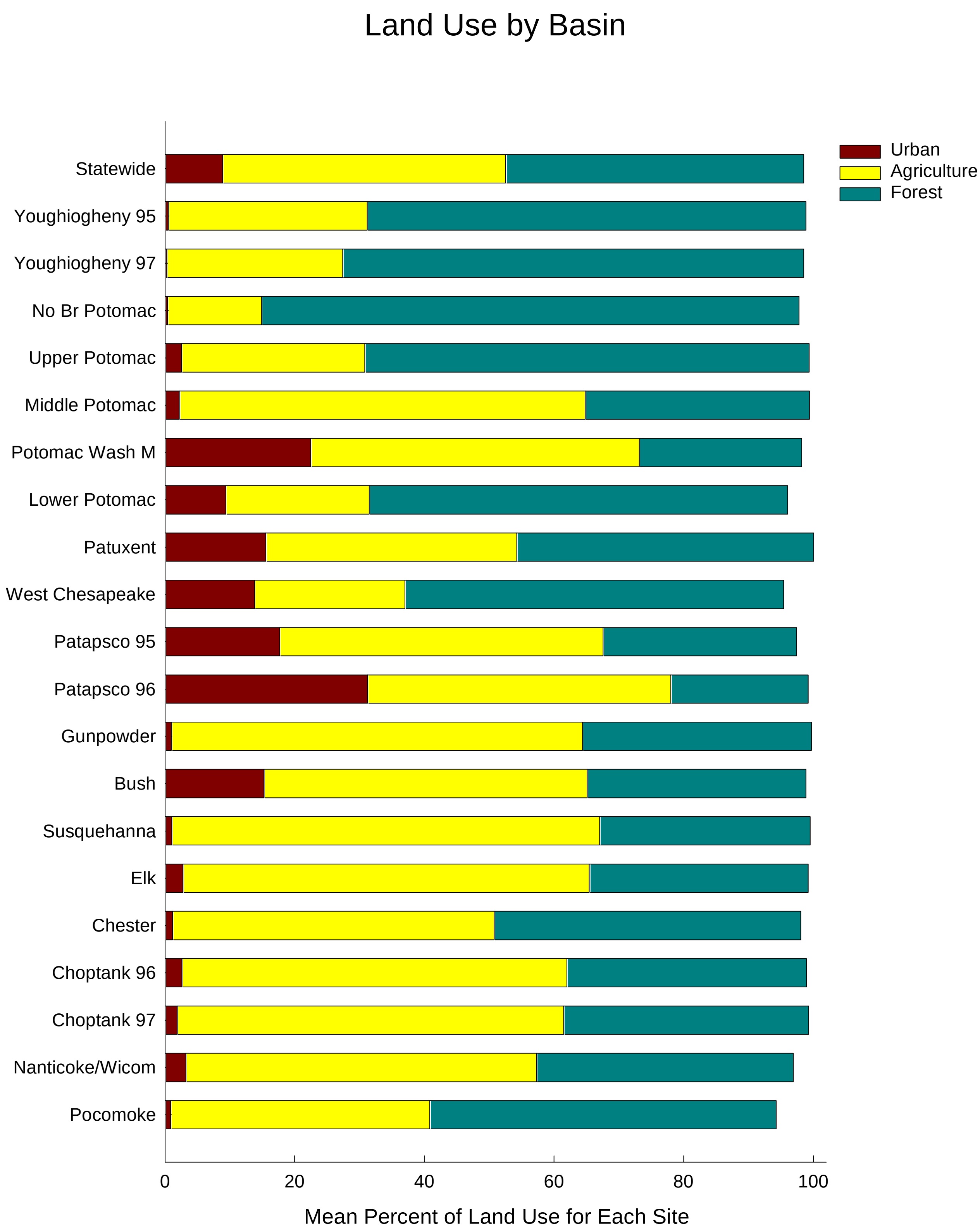
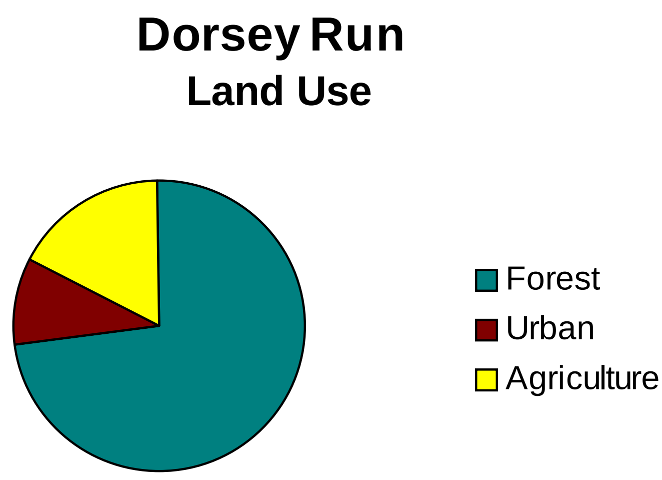


Figure 9-1. Major land use types within individual catchments upstream of the 1995-1997 MBSS sampling sites. Values for each basin are the mean percentage of catchment area in each of the land use categories.



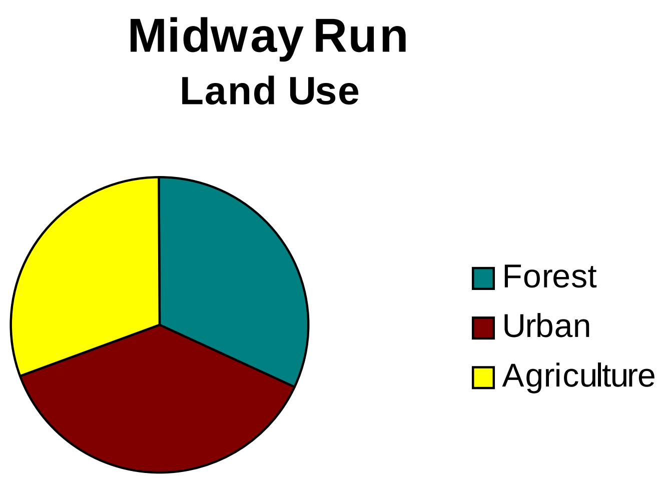


Figure 9-2. Percentage of three land use types (forest, urban, and agriculture) for two streams in the Patuxent basin - Dorsey Run and Midway Run

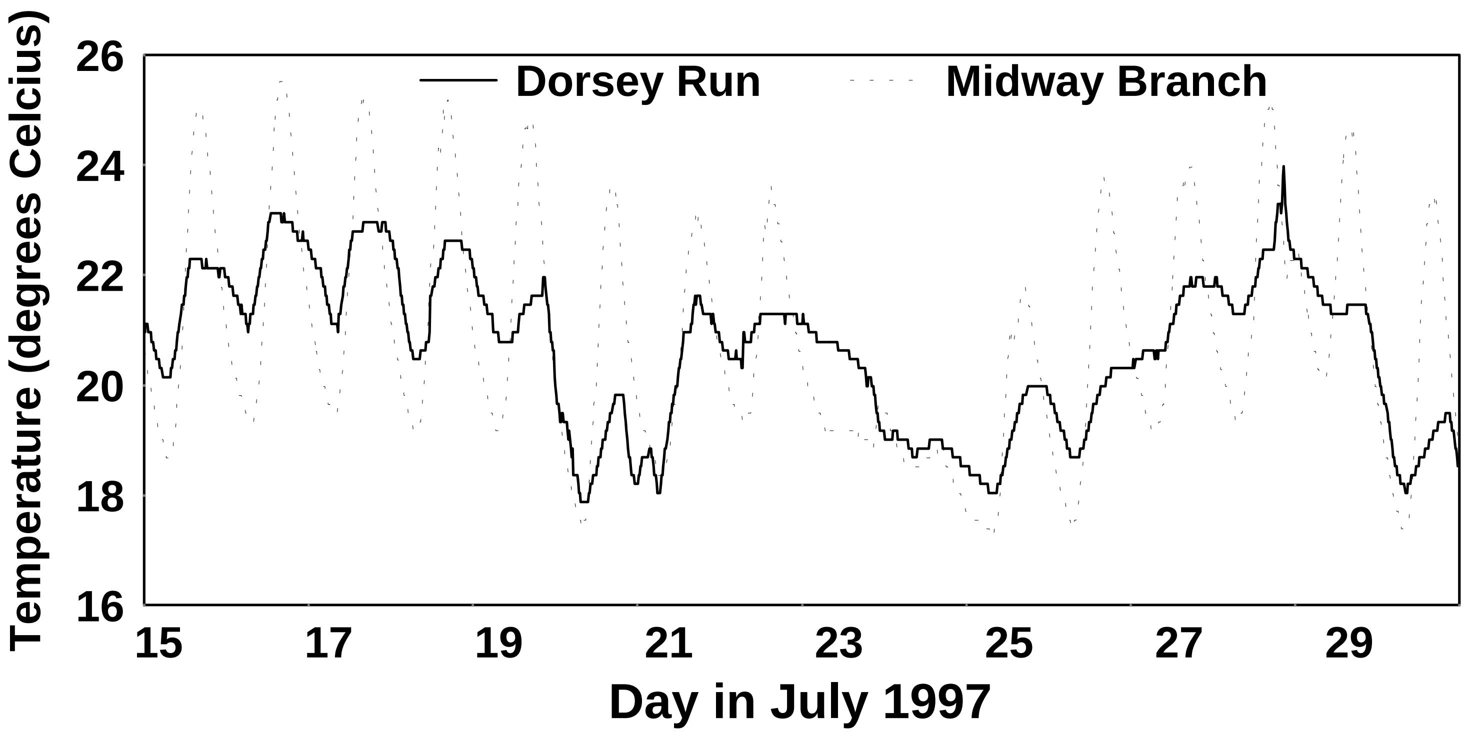


Figure 9-3. Water temperature (◦C) during July 1997 for two streams in the Patuxent basin - Dorsey Run and Midway Run

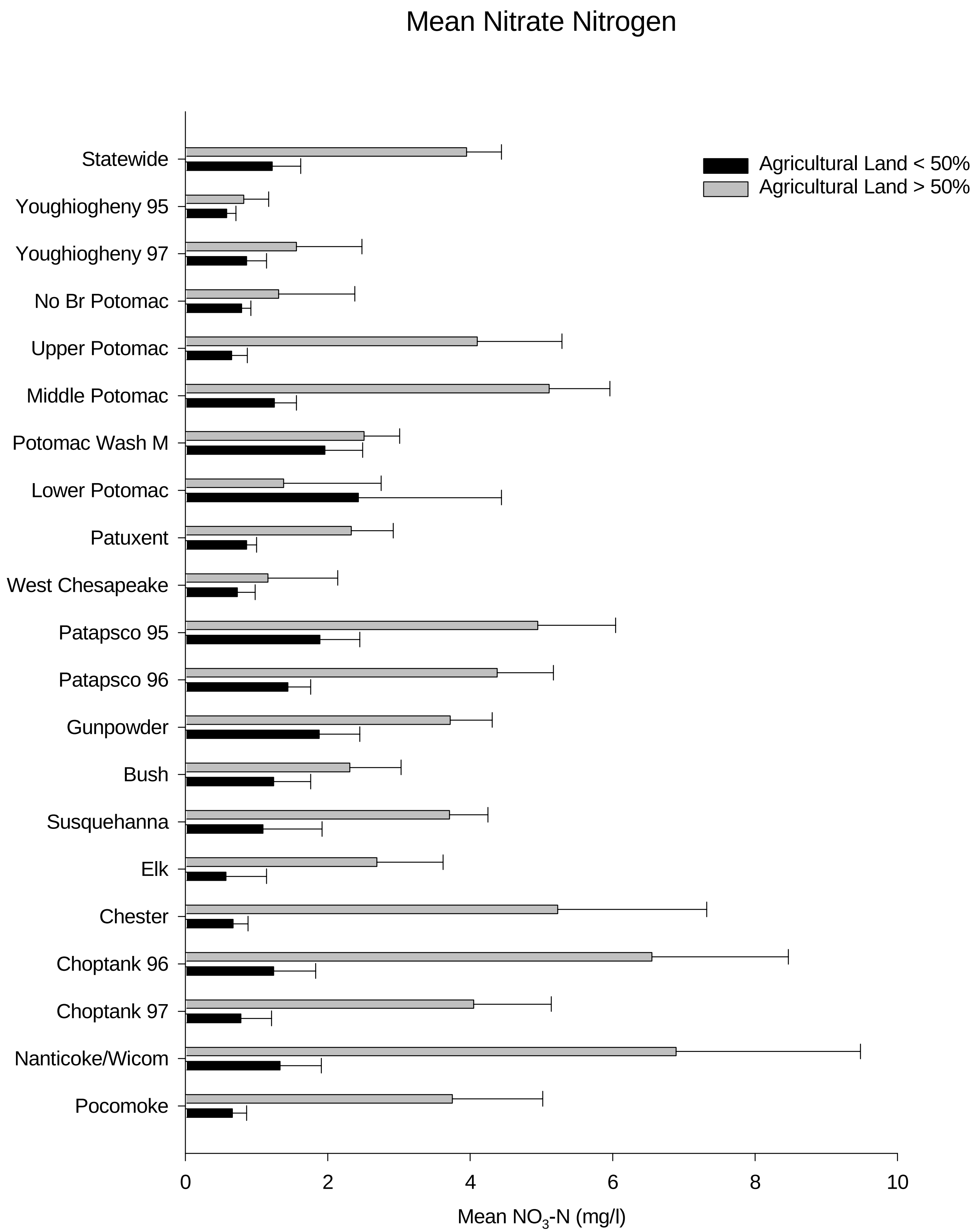


Figure 9-4. Mean nitrate-nitrogen concentration (mg/l), statewide and for basins sampled in the 1995-19979 MBSS, among sites with catchment land use less than and greater than 50% agriculture

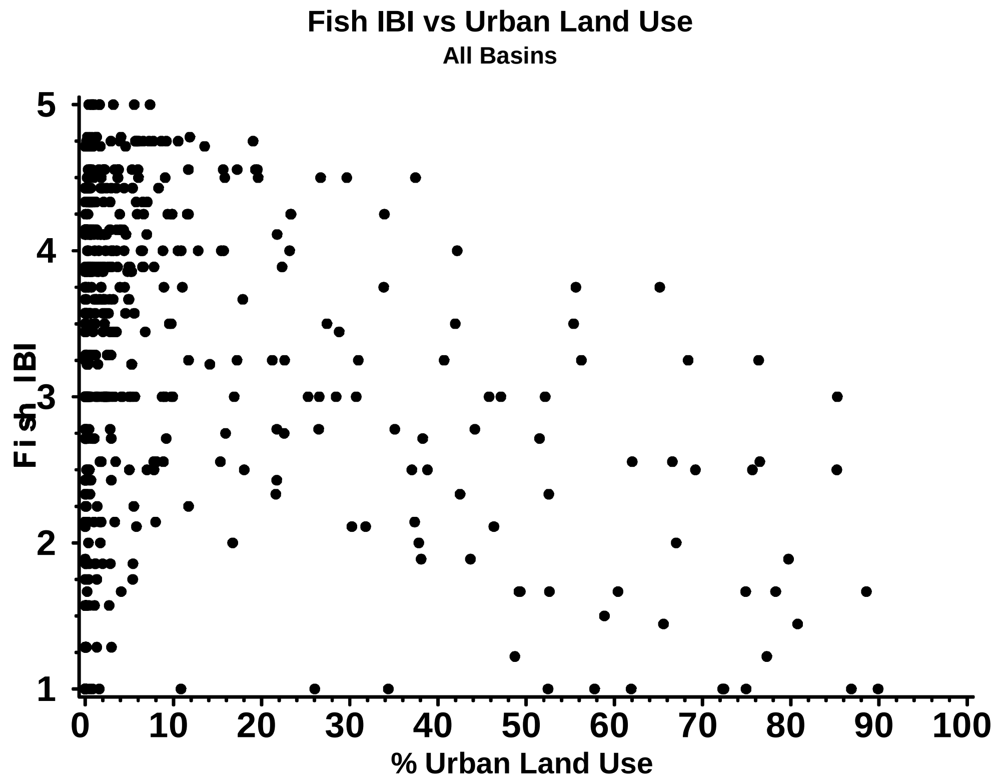


Figure 9-5. Relationship between the fish IBI and urban land use for the basins sampled in the 1995-1997 MBSS

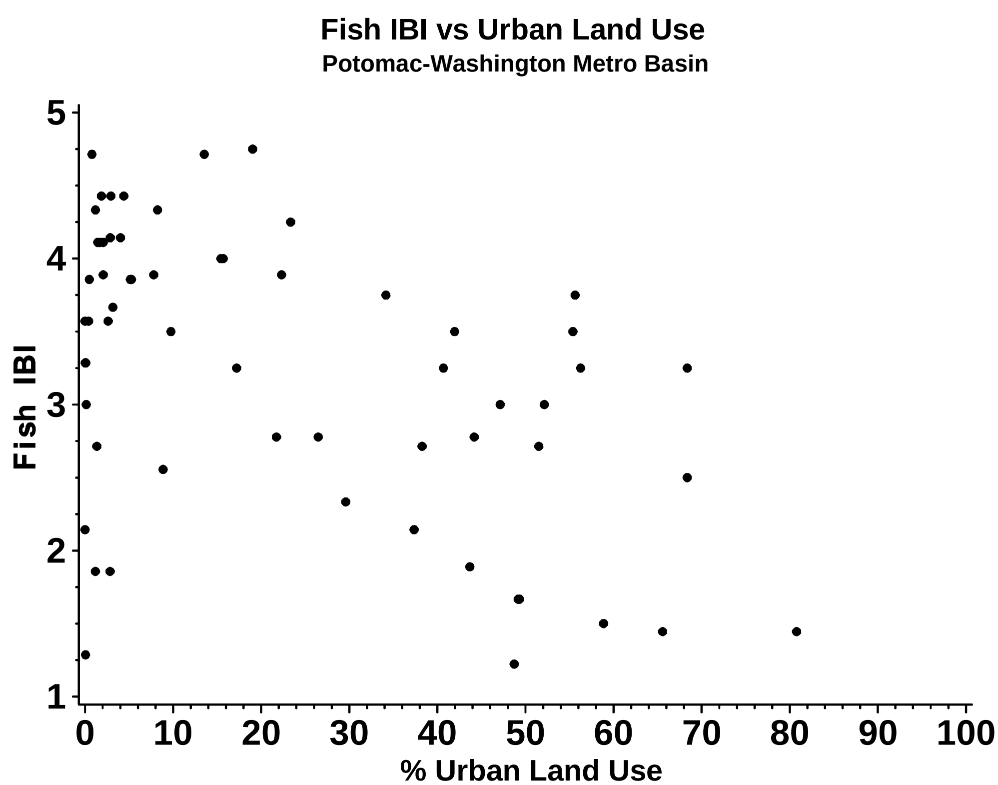


Figure 9-6. Relationship between the fish IBI and urban land use for the Potomac Washington Metro basin

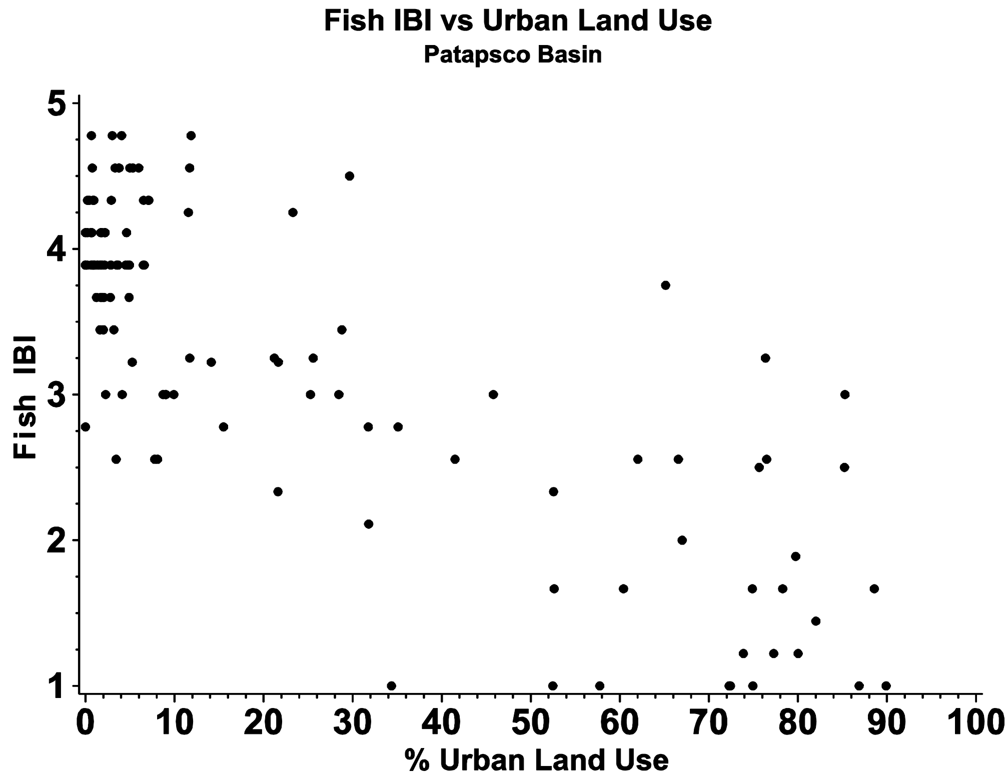


Figure 9-7. Relationship between the fish IBI and urban land use for the Patapsco basin

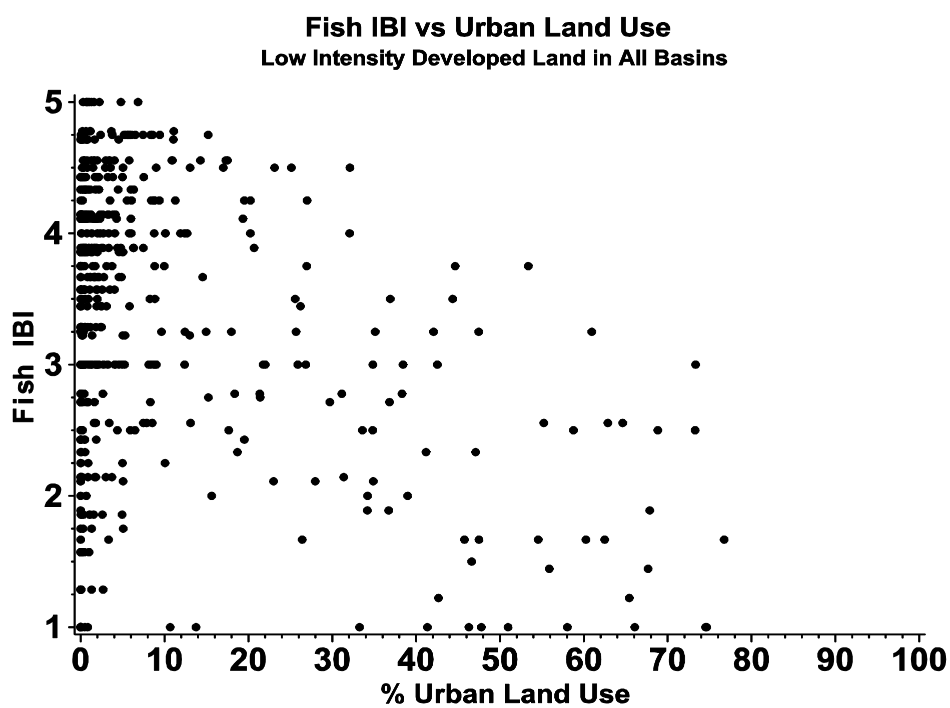


Figure 9-8. Relationship between the fish IBI and low-intensity development for the basins sampled in the 1995-1997 MBSS

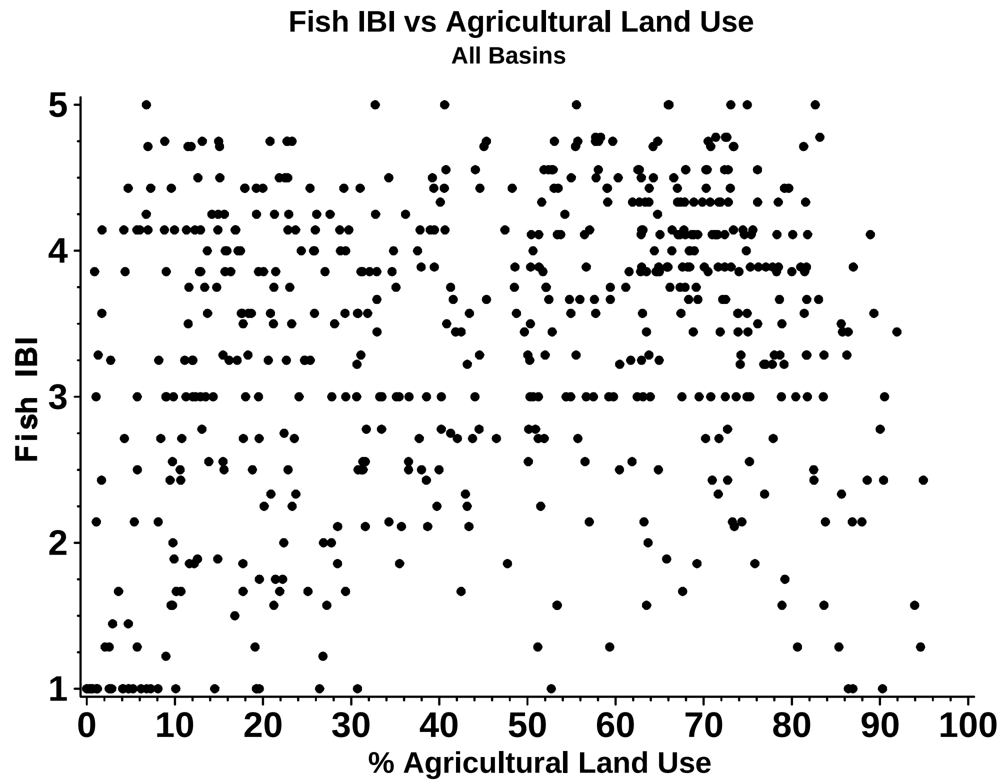


Figure 9-9. Relationship between the fish IBI and agricultural land use for the basins sampled in the 1995-1997 MBSS

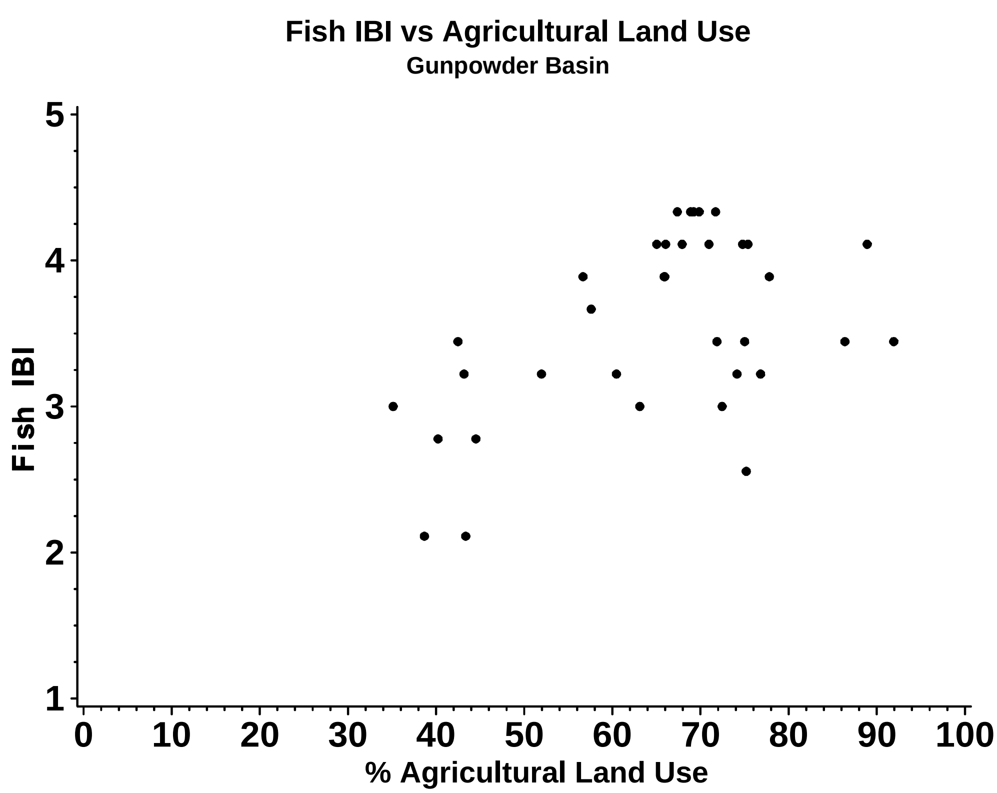


Figure 9-10. Relationship between the fish IBI and agricultural land use for the Gunpowder basin

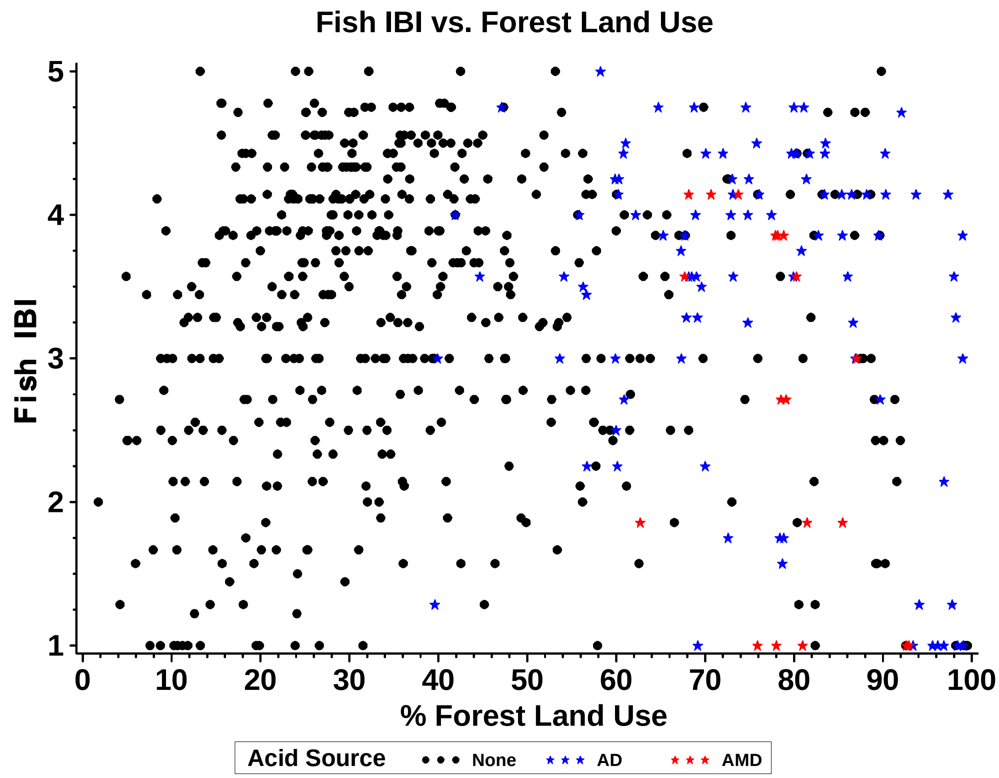


Figure 9-11. Relationship between the fish IBI and forested land cover for the basins sampled in the 1995-1997 MBSS. Blue stars indicate sites affected by acid deposition (AD); red stars indicate acid mine drainage (AMD).

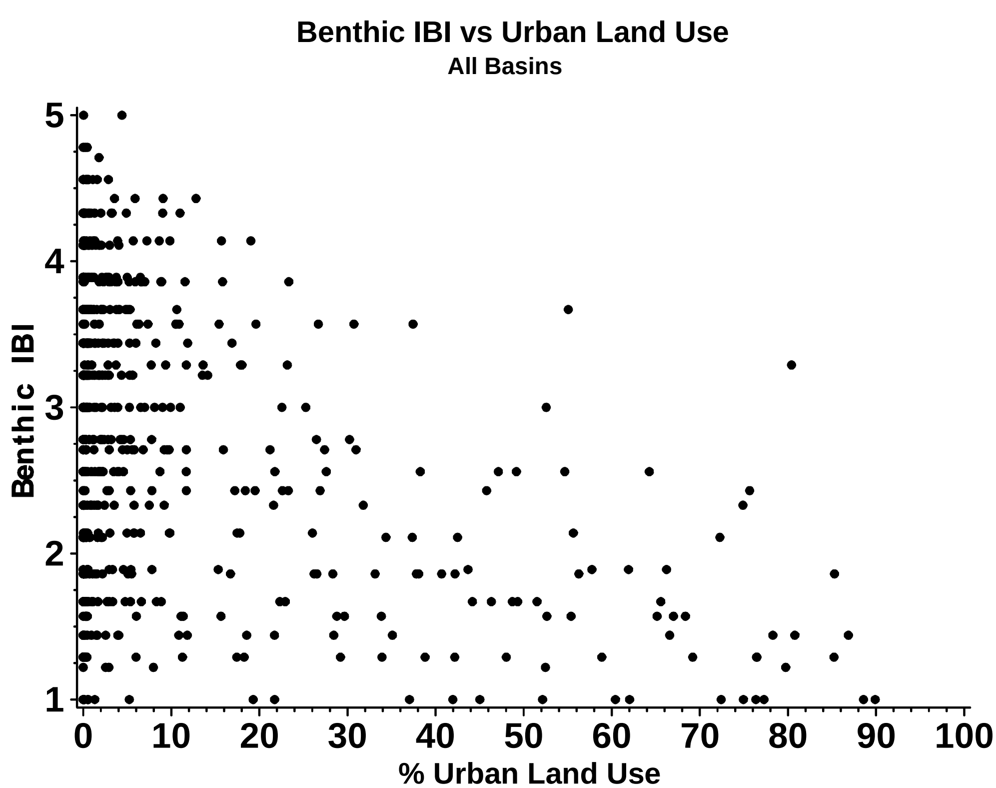


Figure 9-12. Relationship between the benthic IBI and urban land use for the basins sampled in the 1995-1997 MBSS

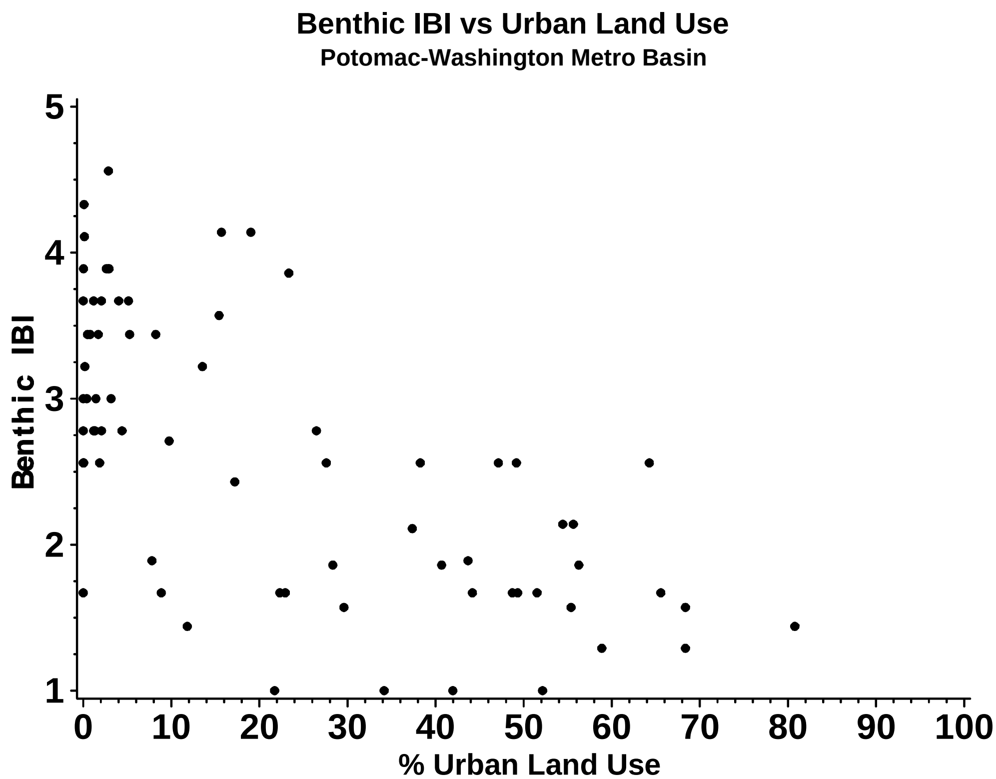


Figure 9-13. Relationship between the benthic IBI and urban land use for the Potomac Washington Metro basin

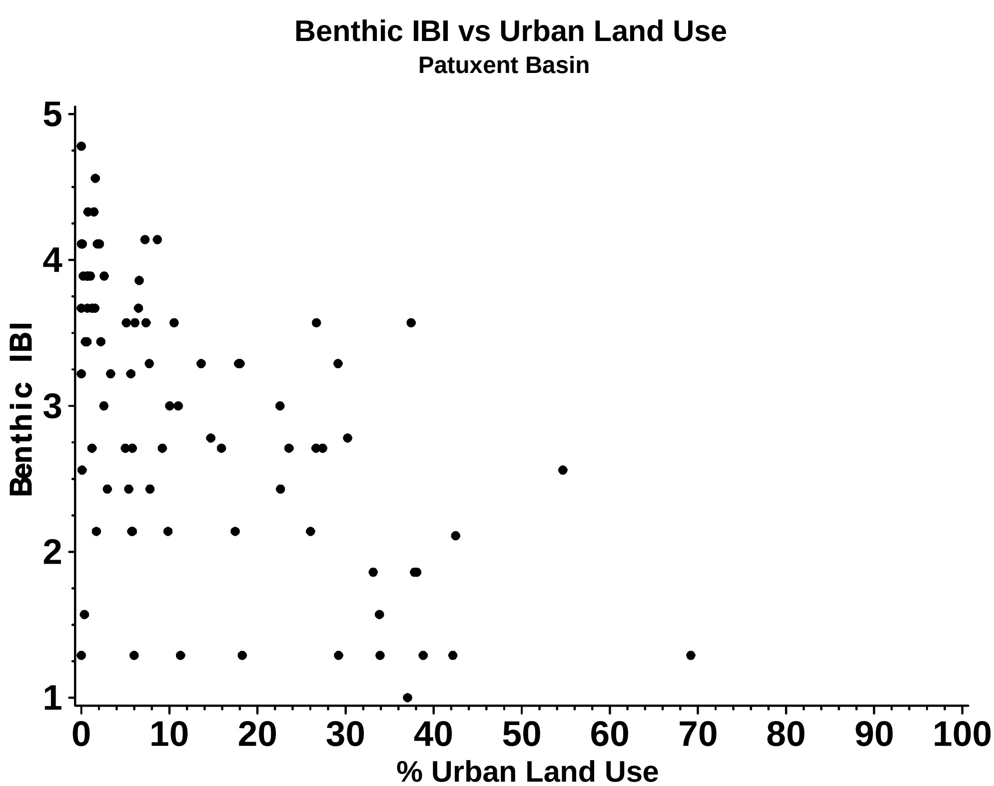


Figure 9-14. Relationship between the benthic IBI and urban land use for the Patuxent basin

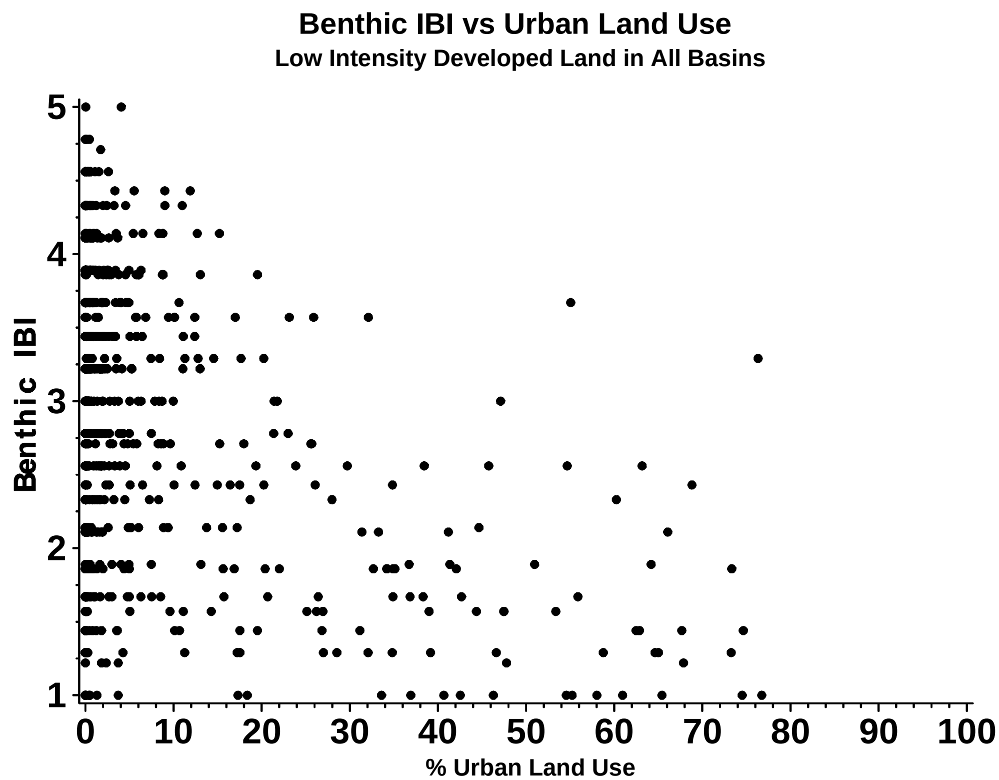


Figure 9-15. Relationship between the benthic IBI and low-intensity development for the basins sampled in the 1995-1997 MBSS

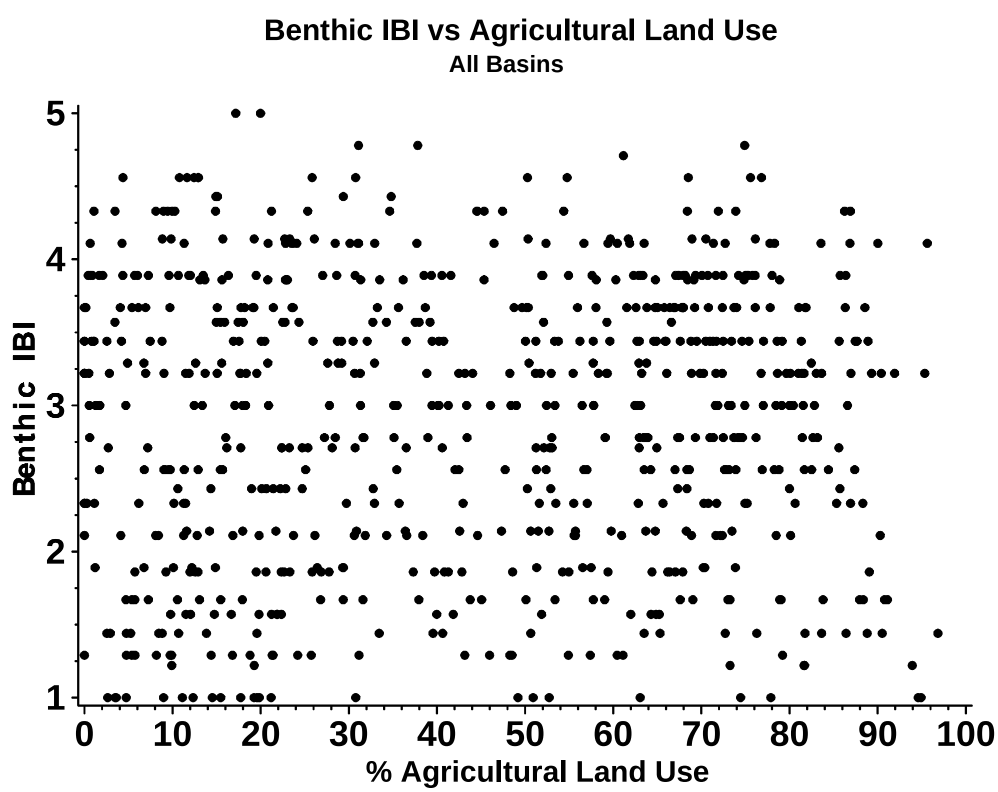


Figure 9-16. Relationship between the benthic IBI and agricultural land use for the basins sampled in the 1995-1997 MBSS

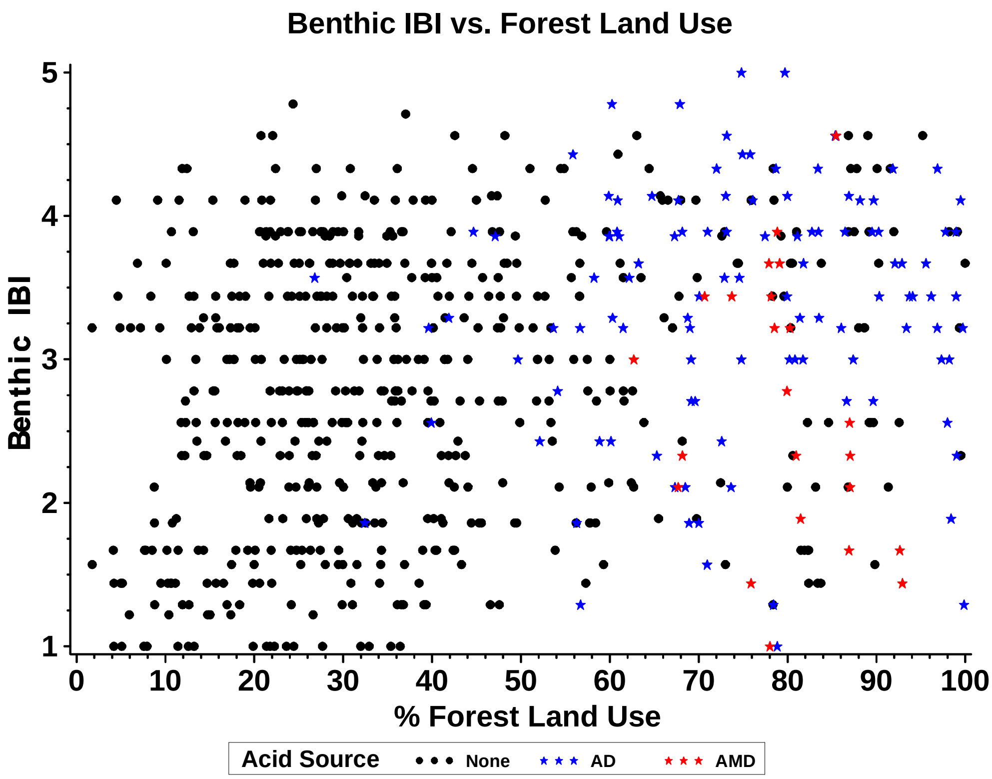


Figure 9-17. Relationship between the benthic IBI and forested land cover for the basins sampled in the 1995-1997 MBSS. Blue stars indicate sites affected by acid deposition (AD); red stars indicate acid mine drainage (AMD).

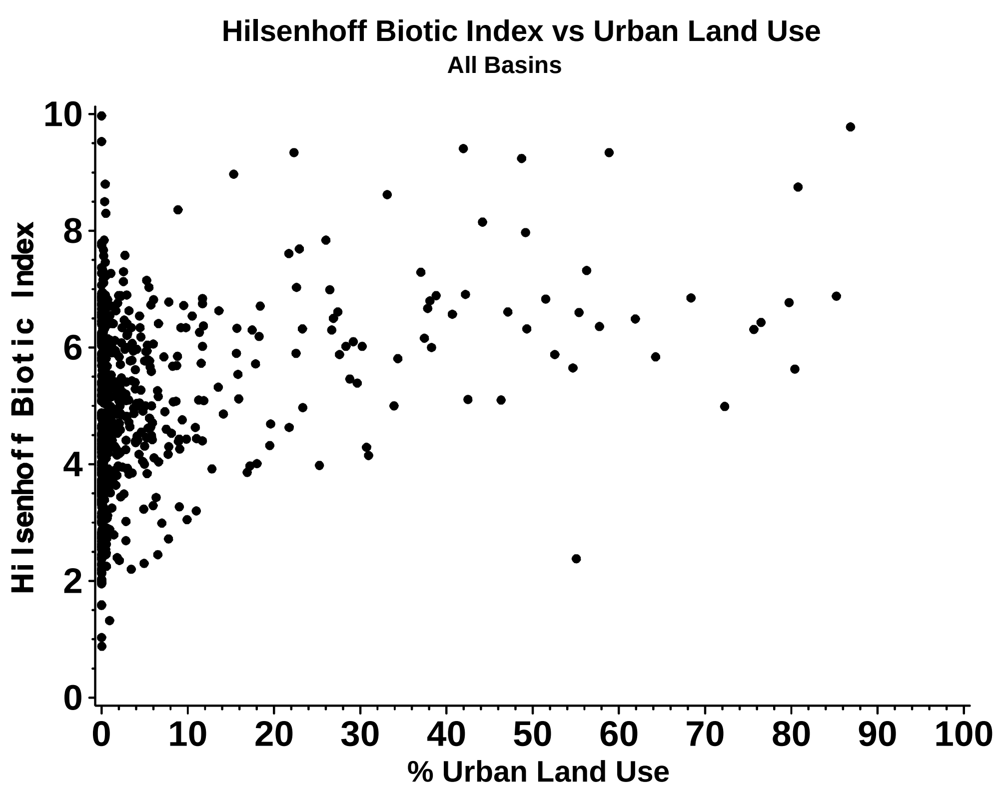


Figure 9-18. Relationship between the Hilsenhoff Biotic Index and urban land use for the basins sampled in the 1995-1997 MBSS

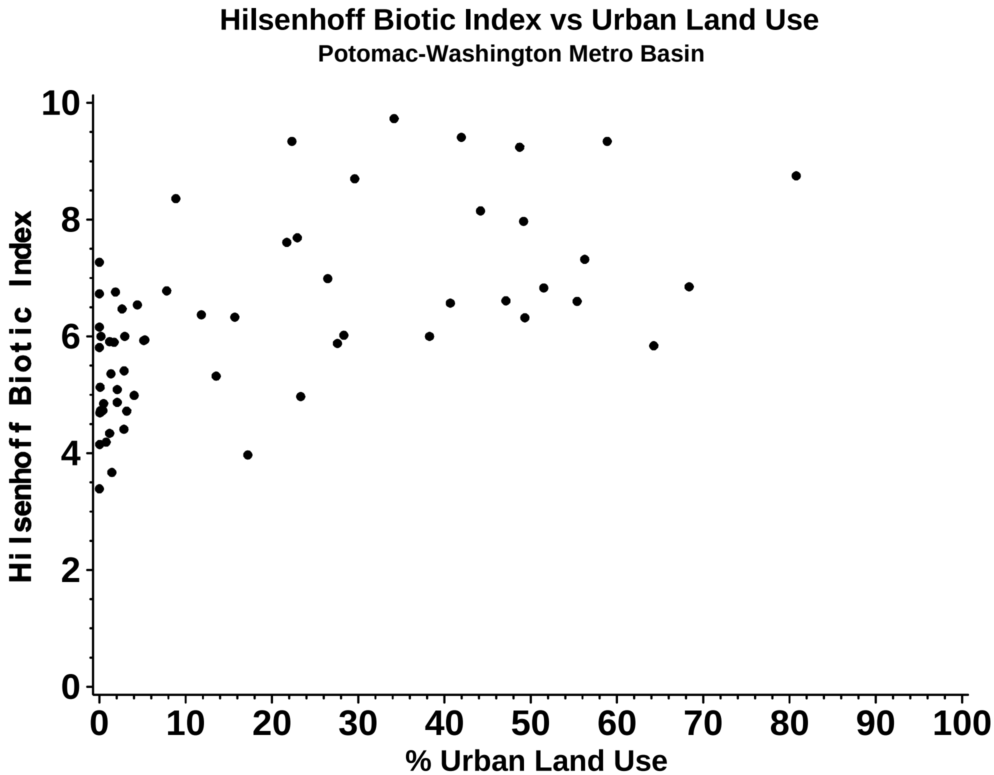


Figure 9-19. Relationship between the Hilsenhoff Biotic Index and urban land use for the Potomac Washington Metro basin

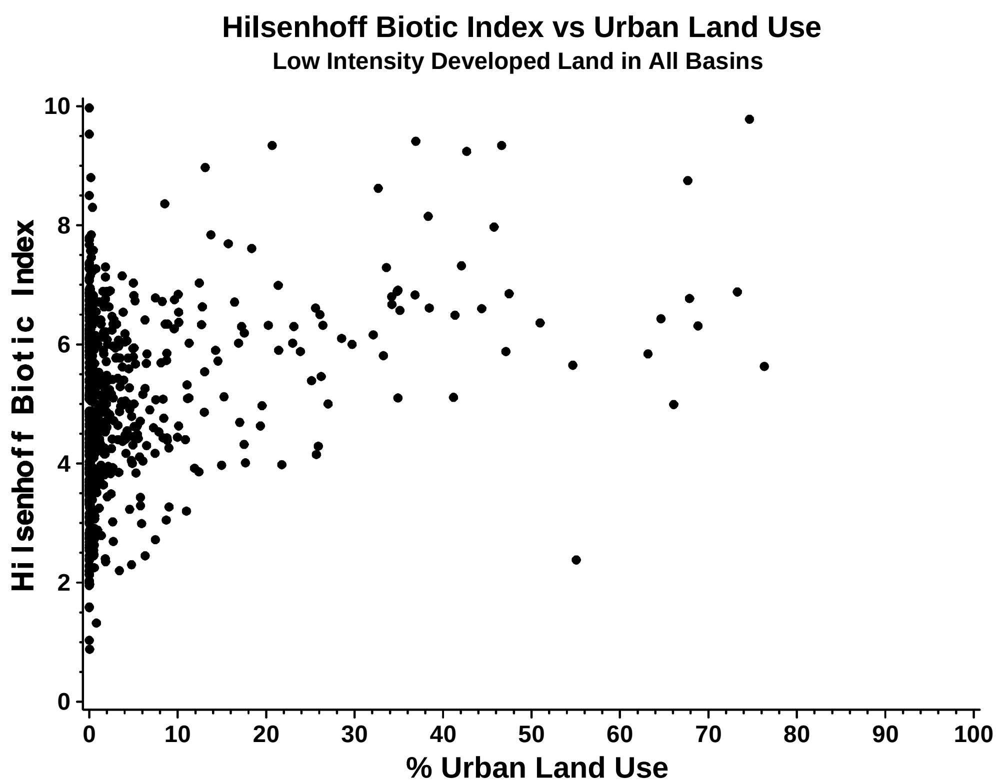


Figure 9-20. Relationship between the Hilsenhoff Biotic Index and low-intensity development for the basins sampled in the 1995-1997 MBSS

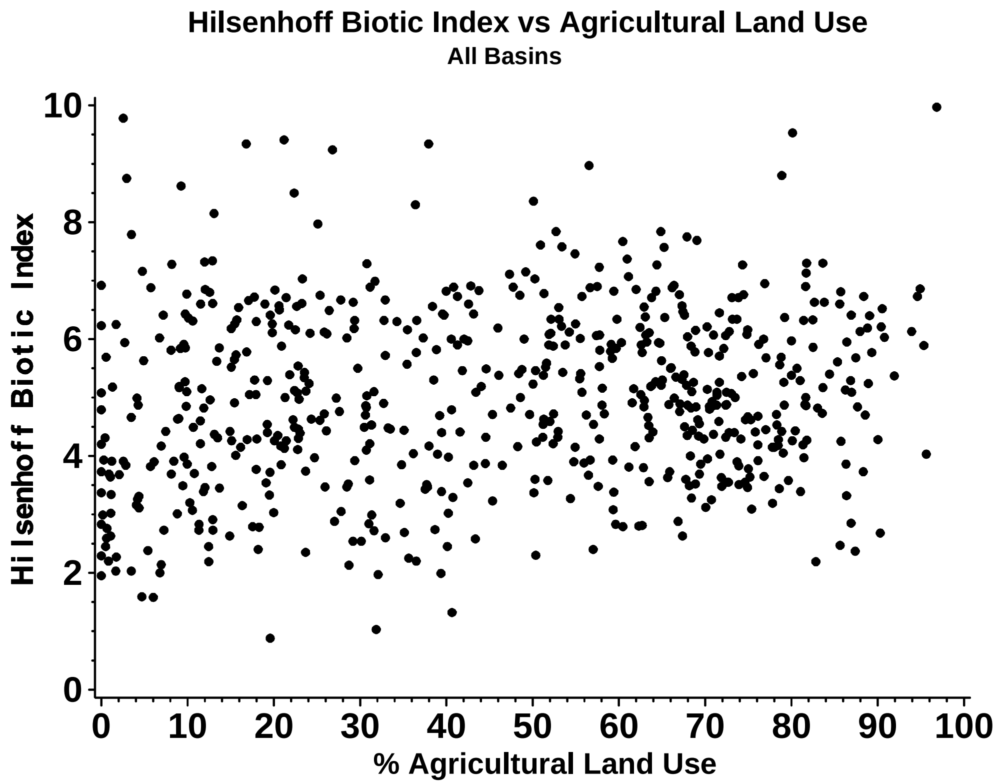


Figure 9-21. Relationship between the Hilsenhoff Biotic Index and agricultural land use for the basins sampled in the 1995-1997 MBSS

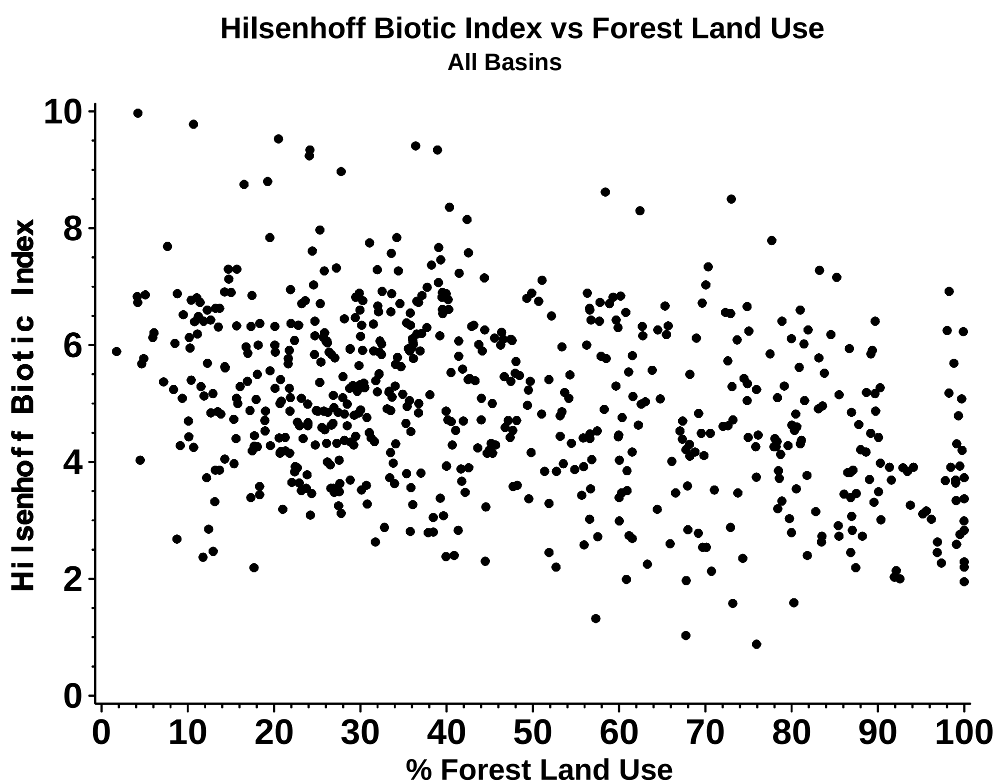


Figure 9-22. Relationship between the Hilsenhoff Biotic Index and forested land cover for the basins sampled in the 1995-1997 MBSS

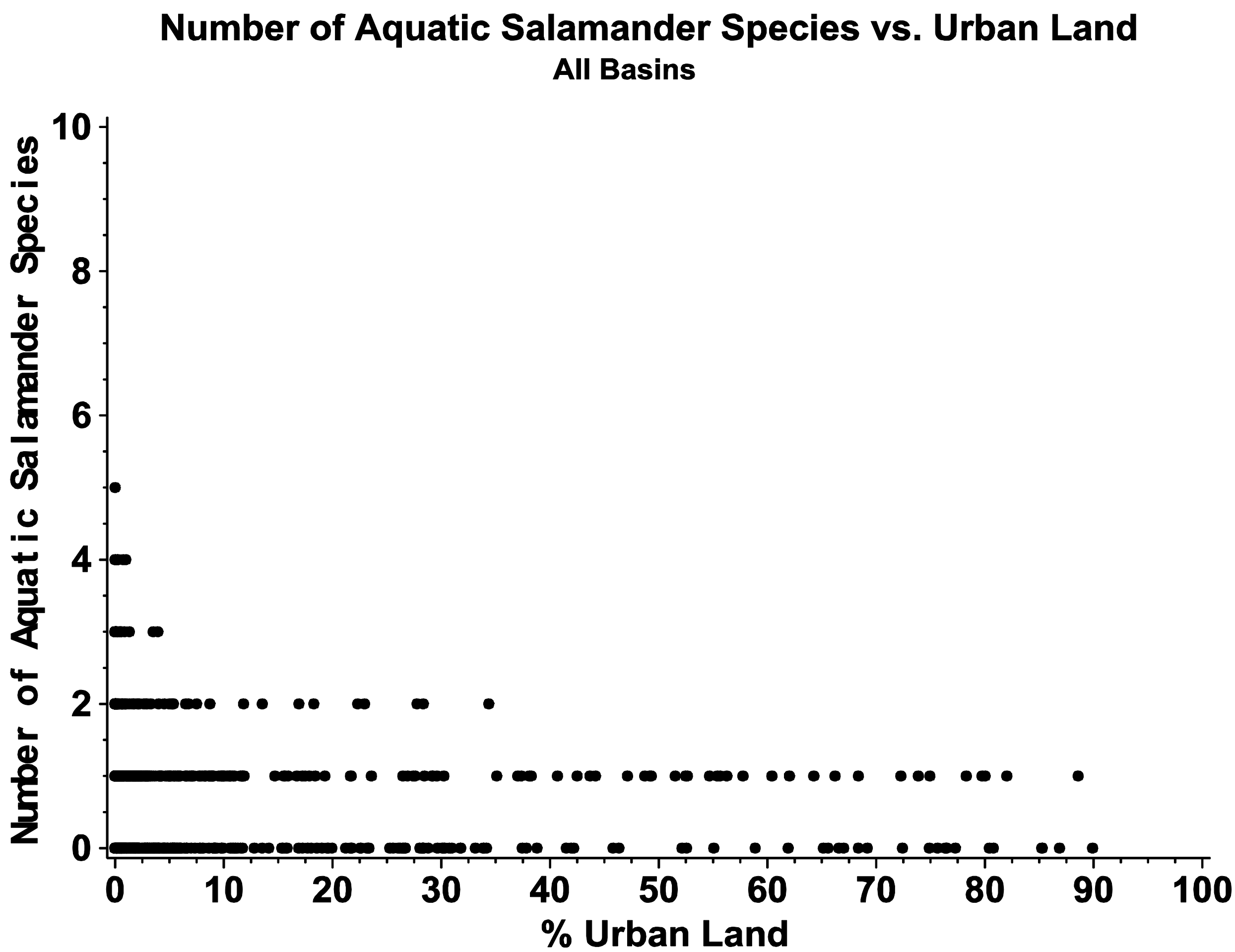
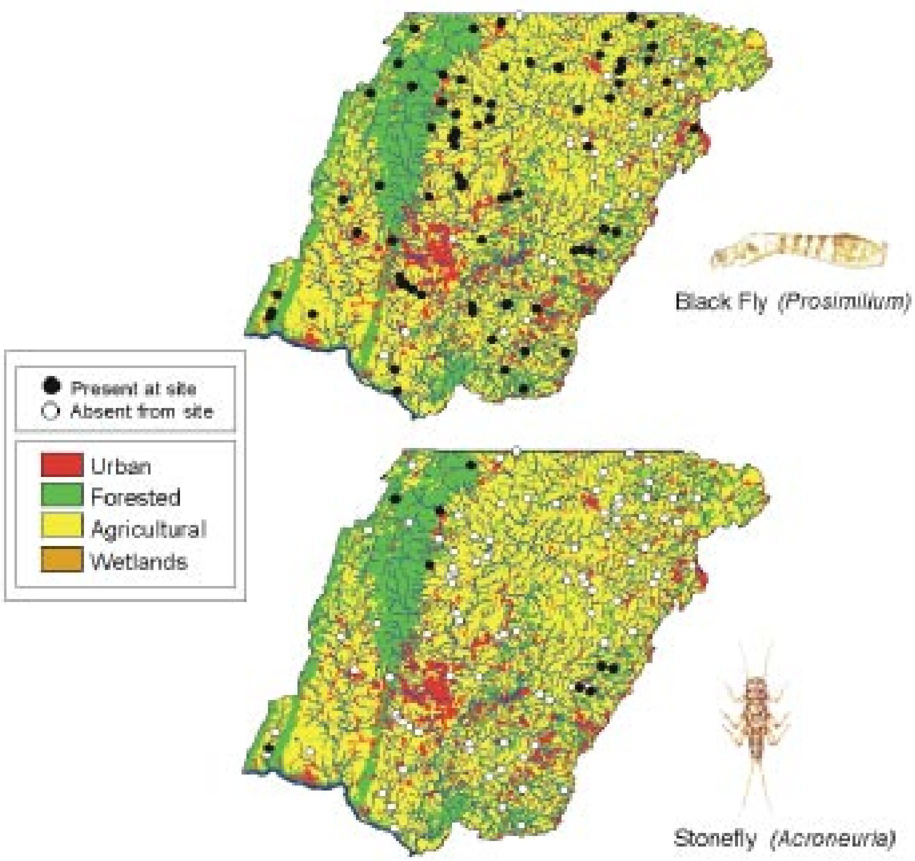


Figure 9-23. Relationship between the number of aquatic salamanders per site and urban land use for the basins sampled in the 1995-1997 MBSS

Benthic Taxa as Indicators of Stream Degradation

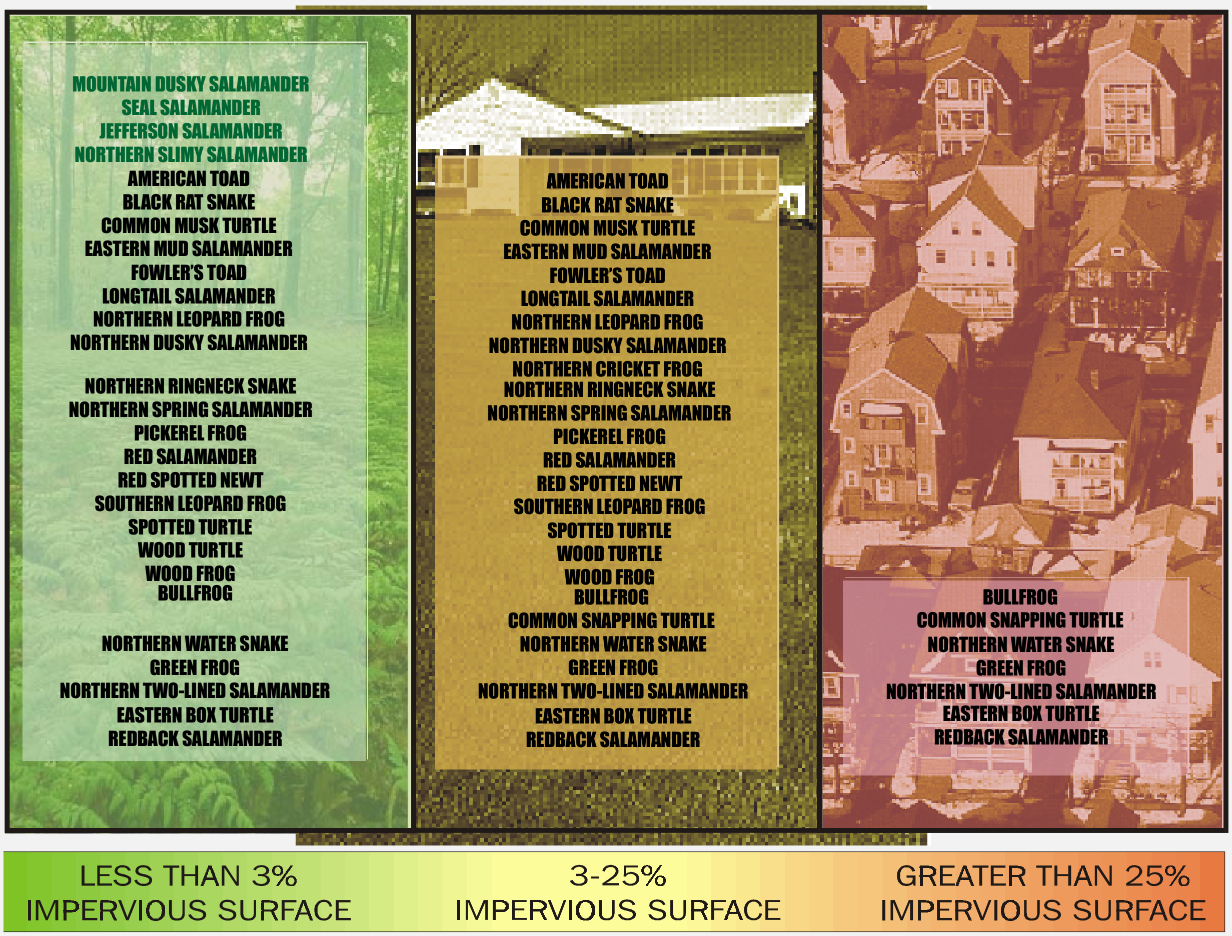
The presence or absence of certain benthic macroinvertebrate taxa can indicate the effects of watershed land uses. For example, the stonefly *Acroneuria* is pollution-sensitive and survives only among clean rocks in streams with cool, swiftly-moving water and a good amount of dissolved oxygen. In the Middle Potomac River basin, which is mostly agricultural land, these insects were found at only 9 of the 109 sites sampled and primarily in the heavily-forested mountains in the western part of the basin. Streams here are likely to be less polluted by sediment, nutrients, pesticides, and herbicides that often enter streams in runoff from agricultural areas. However, the more pollution-tolerant black fly , *Prosimulium,* was found throughout the basin - in forested, agricultural, and urban watersheds. These insects can live in degraded streams in the more developed areas of the basin. Combined influences of land uses on the entire benthic community – changing the relative abundance of tolerant and sensitive species – are reflected in community-based indicators such as the benthic IBI.



In the Middle Potomac basin, sensitive *Acroneuria* stoneflies were found in less-disturbed streams, while tolerant *Prosimilium* tolerated a wide range of land use conditions.

Amphibians and Reptiles Sensitive to Urbanization

A number of amphibians and reptile species appear to be particularly sensitive to the effects of urban development. Of the 29 aquatic or riparian species of amphibians and reptiles found during the survey, only seven occurred in heavily-urbanized areas (>25% imperfious land cover in the upstream watershed). At the opposite end of the scale, four species of salamanders (in blue) never occurred in urbanized areas (>3%) impervious land cover).



10 INTERANNUAL VARIABILITY

Maryland Biological Stream survey (MBSS or Survey) results are presented in this report for basins sampled across three sampling years (1995, 1996, and 1997). We recognize that variation in environmental conditions may influence results from different years. In particular, annual changes in weather conditions can affect stream chemistry, physical habitat, and biological communities. To evaluate the degree to which year-to-year variation in weather conditions may have affected MBSS results, we analyzed variability in precipitation and potential effects on several parameters measured during the 1995-1997 MBSS.

10.1 VARIABILITY OF PRECIPITATION

Across Maryland, 1996 was an exceptionally wet year. January and September were marked by extreme flooding in many areas. According to regional precipitation data (NOAA 1996), the areas sampled by the MBSS received between 20% and 52% more rainfall than normal during 1996. The sample years of 1995 and 1997 were much drier, with regions receiving up to 21% less rainfall than normal (NOAA 1995 and 1997). Statewide, Maryland received an average of 38% more rainfall than normal in 1996. In 1995 and 1997, the State received an average of 7% less rainfall than normal (Figure 10-1). See Appendix D (Table D-1) for summaries of regional precipitation throughout Maryland, during 1995-1997. This difference in annual precipitation was reflected somewhat in the number of dry streams observed during the Survey. During 1996, an estimated 2.8% of stream miles were reported as ephemeral (dry during summer), compared with slightly higher numbers in other years: 5.3% in 1995 and 4.2% in 1997.

10.2 COMPARISON OF RESULTS FOR BASINS SAMPLED IN MULTIPLE YEARS

As part of the MBSS's lattice sampling design (Section 2.1), one randomly-selected basin in each geographic region (western, central, and eastern Maryland) was sampled in each of two separate years to quantify between-year variability in the response variables. The "resampled" basins and the two years in which they were sampled are as follows:

Youghiogheny: 1995 and 1997
Patapsco: 1995 and 1996
Choptank: 1996 and 1997

Data from the same basin collected in two years provide some means of examining annual differences in basin conditions. A more rigorous analysis of trends over time will require additional data from future surveys that span more years.

Nonetheless, the data currently available allow us to examine the degree to which year-to-year variation influenced the interpretation of the 1995-1997 statewide and basin-specific estimates. For example, field data for stream discharge in the resampled basins is compared in Figure 10-2. In the Patapsco basin, mean discharge was much higher in 1996 (4.7 cubic feet per second) than in 1995 (2.1 cfs). In the Choptank, discharge was slightly higher in 1996 (2.8 cfs) than 1997 (1.9 cfs), although these values were within one standard error. In both cases, observed differences were consistent with the greater amount of rainfall received in 1996.

10.3 COMPARISON OF SELECTED BIOLOGICAL AND WATER QUALITY RESULTS FOR BASINS SAMPLED IN MULTIPLE YEARS

For each of the resampled basins, we compared the mean values in the two sample years for the fish Index of Biotic Integrity (IBI), benthic IBI, the Physical Habitat Index (PHI), and nitrate-nitrogen concentration to evaluate the potential importance of interannual variation. In addition, we compared selected results for individual stream reaches sampled in multiple years.

Although some interannual differences in mean values were detected for the fish, benthic, and physical habitat indices, virtually all were within the range of error around each mean estimate (±1 standard error), indicating no significant change from year to year in any basin (Figures 10-3 to 10-5). The only indicator that showed a significant interannual difference was the benthic IBI in the Patapsco basin, where the mean score was significantly lower in 1996 than in 1995. PHI scores in the Choptank basin were slightly lower in 1997 than 1996, although values were within the range of error. Mean nitrate-nitrogen concentrations did not vary significantly between years in any of the resampled basins (Figure 10-6).

Data from individual stream reaches sampled in multiple years provide an additional means of evaluating interannual

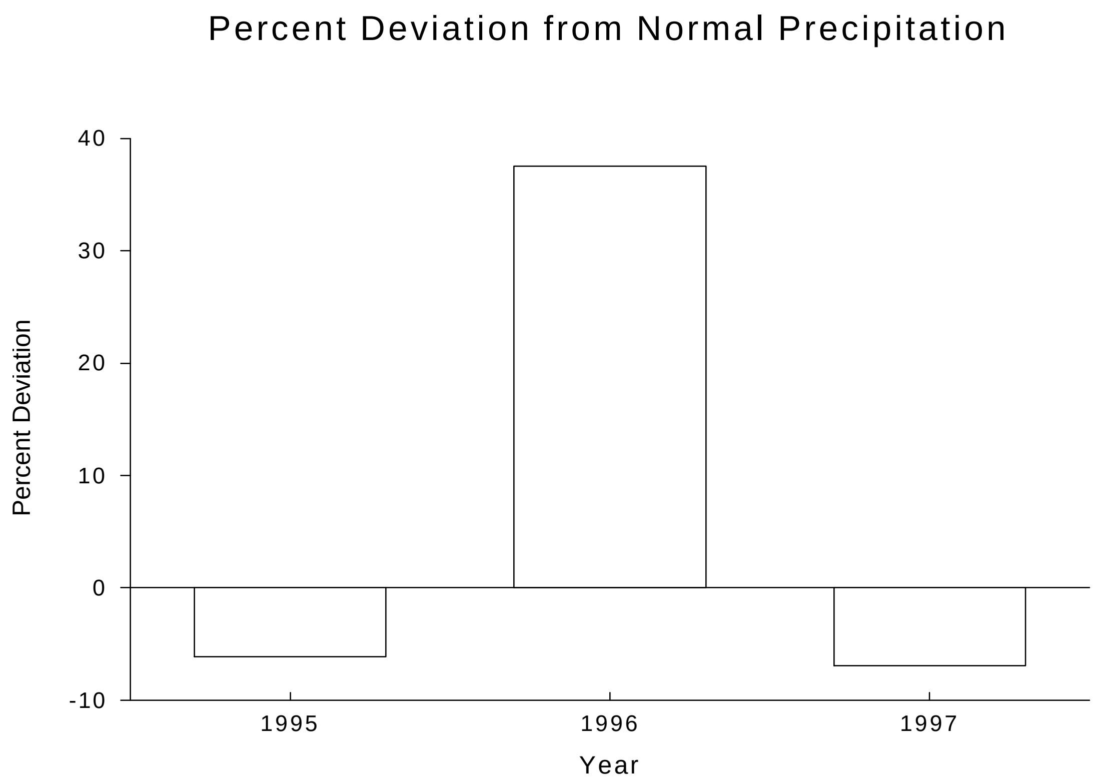


Figure 10-1. Statewide percent deviation from normal precipitation amount for the MBSS sample years 1995-1997 (annual total precipitation)

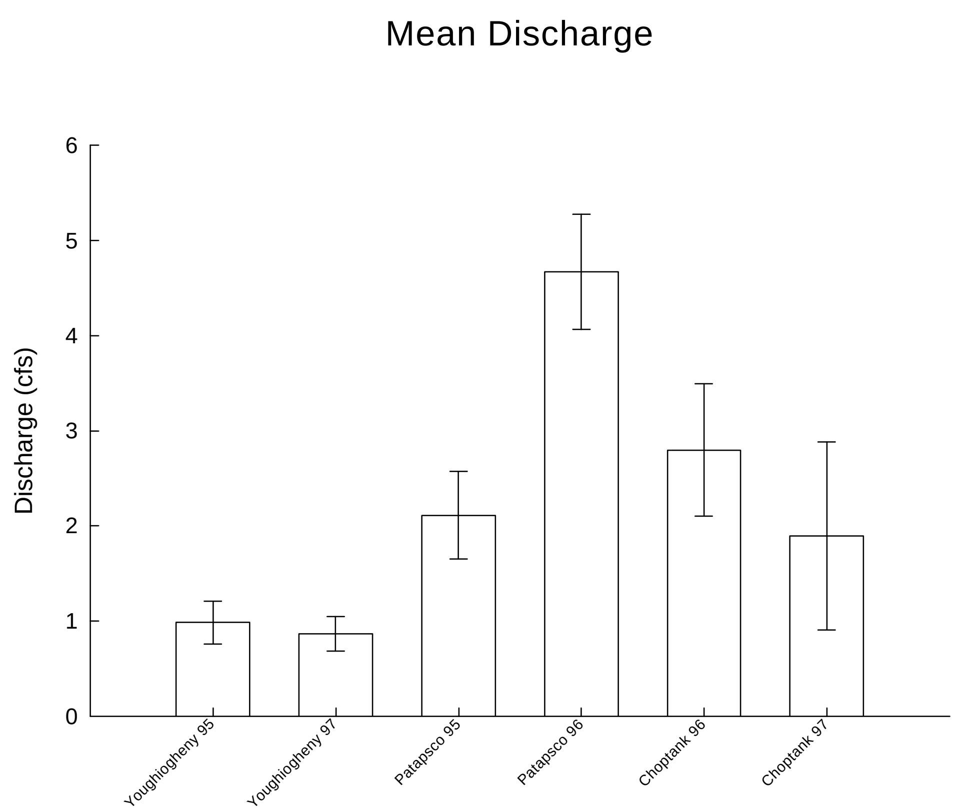


Figure 10-2. Mean discharge (cfs) for the three basins that were sampled in multiple years of the 1995-1997 MBSS. Error bars signify ± standard error.

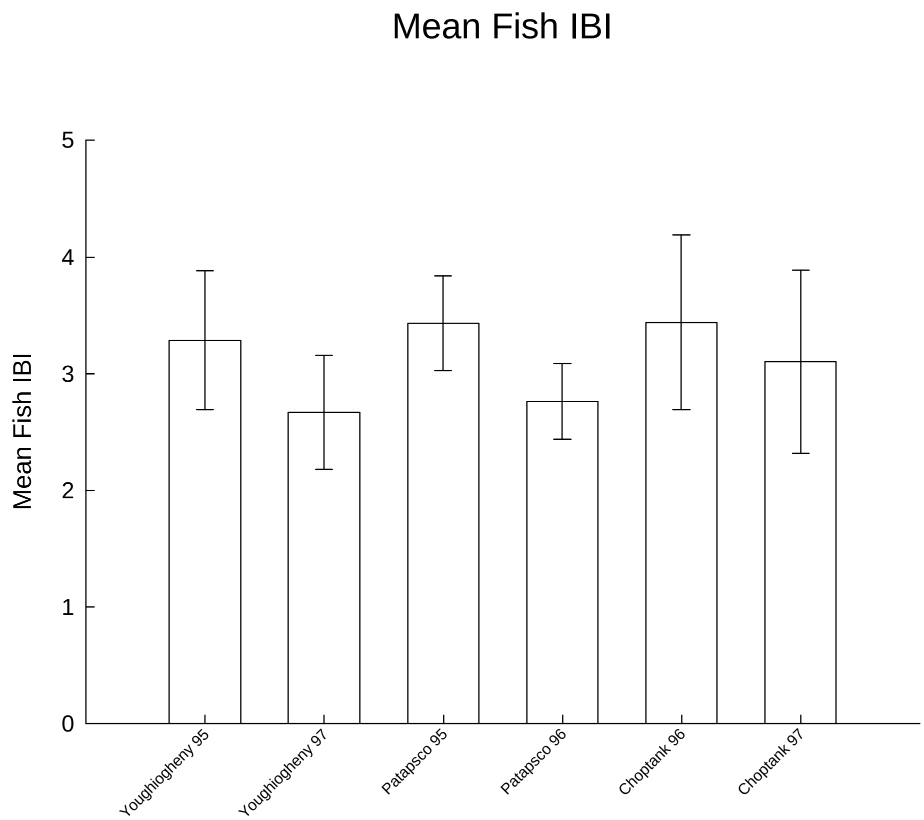


Figure 10-3. Mean fish Index of Biotic Integrity (IBI) scores for the three basins that were sampled in multiple years of the 1995-1997 MBSS. Error bars signify ±1 standard error.

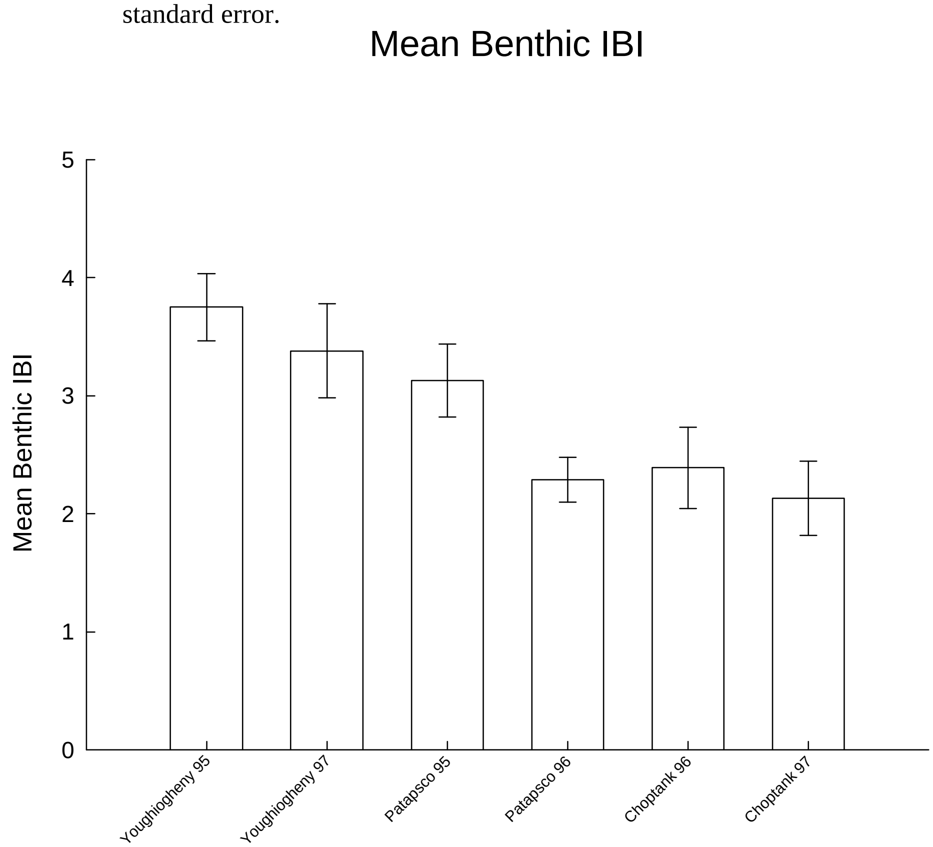


Figure 10-4. Mean benthic Index of Biotic Integrity (IBI) scores for the three basins that were sampled in multiple years of the 1995-1997 MBSS. Error bars signify ±1 standard error.

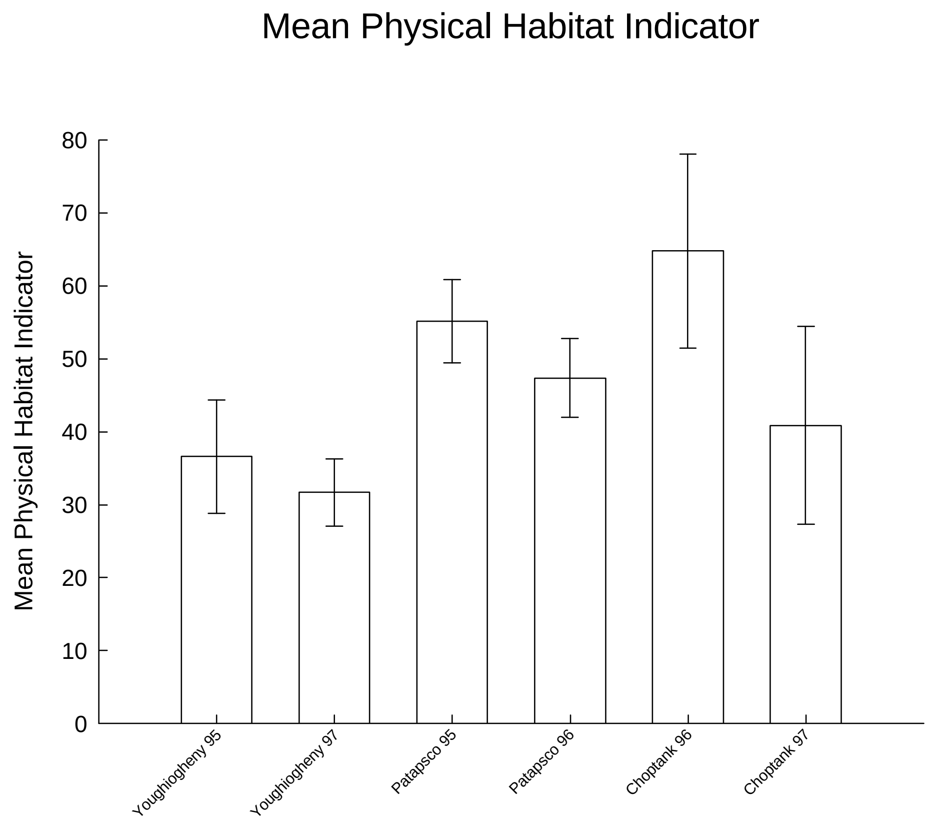


Figure 10-5. Mean Physical Habitat Indicator scores for the three basins that were sampled in multiple years of the 1995-1997 MBSS. Error bars signify ±1 standard error.

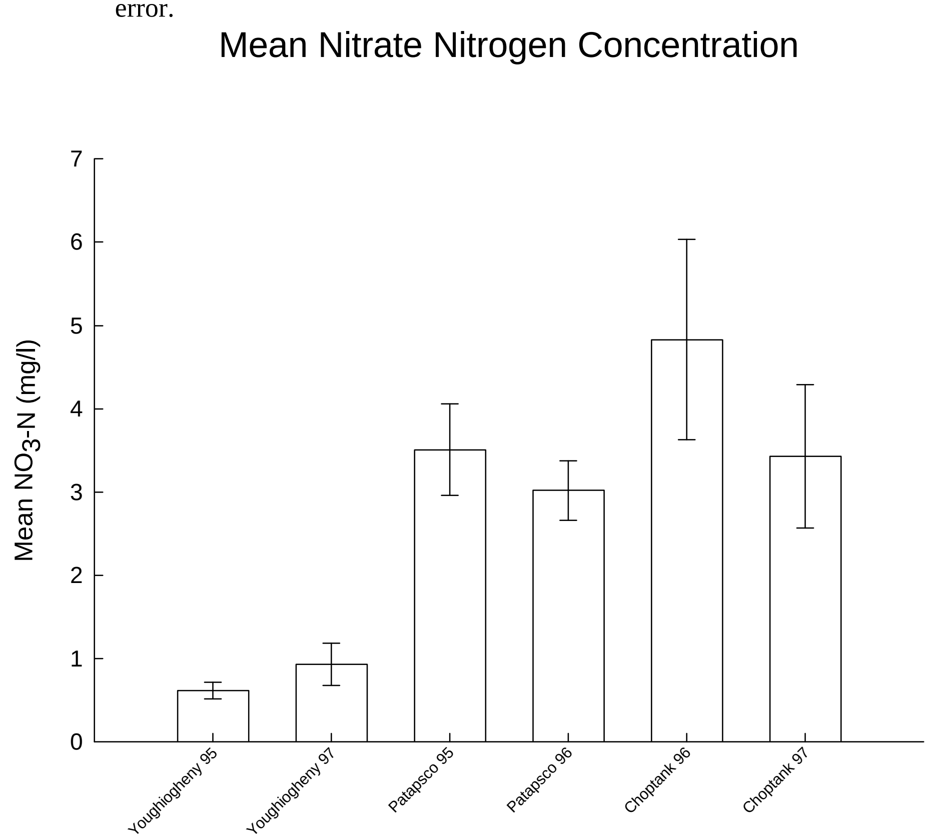


Figure 10-6. Mean nitrate nitrogen (NO_3-N) concentrations (mg/l) for the three basins that were sampled in multiple years of the 1995-1997 MBSS. Error bars signify ± standard error.

variation. As a result of random site selection, 17 stream reaches within the resampled basins were revisited in multiple years: 4 in Youghiogheny, 11 in Patapsco, and 2 in Choptank (Appendix D, Table D-2). Fish IBI, benthic IBI, PHI, nitrate-nitrogen concentration, and discharge for the same reach were compared between years. When more than one site per reach was sampled in a single year, the mean value for all sites in that year was used in this comparison.

At all of the 14 reaches sampled during two summers, discharge changed by at least 10% between years. Except for one reach, discharge was higher in 1996 than 1995 or 1997. In contrast, PHI scores were fairly consistent (within ±15 points on a 100 point scale) at 8 of the 14 reaches. In 1996 sampling of the Patapsco basin, where discharge was noticeably affected by higher rainfall, PHI scores increased at only one reach, decreased at one other, and remained the same at seven reaches, in comparison with 1995 levels. Generally, fish IBI scores were consistent between years (within ±0.5 points on a 1-5 scale) at 7 of 14 reaches. Most of the differences in fish IBI scores were in the Patapsco basin, with decreases noted at 6 of 9 reaches sampled in both 1995 and 1996. However, fish IBI also decreased at one site in the Choptank in 1997 (the drier of two years sampled), and increased at one site in the Youghiogheny in 1997, compared to 1995.

Among the 17 reaches sampled during the spring of two years, benthic IBI scores were relatively unchanged (within ±0.5 points on a 1-5 scale) at 8 reaches. Again, the greatest difference was seen in the Patapsco basin, where 5 reaches had lower benthic IBI scores in 1996, along with 2 reaches exhibiting higher scores and 4 unchanged. Nitrate-nitrogen concentrations were relatively unchanged (within ±10%) at 8 of the 11 resampled reaches in the Patapsco basin. Compared to 1995, nitrate-nitrogen increased at all 4 of the resampled reaches in the Youghiogheny in 1997, but the levels were low and well below the state average.

Although based on a very small number of observations, this analysis suggests that benthic and fish IBI scores may vary slightly from year to year, but are not clearly related to precipitation. Physical habitat ratings were fairly consistent; again, small differences could not be attributed to higher precipitation in 1996. Nitrate-nitrogen concentrations neither increased nor decreased predictably with precipitation. Whether the observed differences were a result of natural variation or human impacts is unclear from this limited analysis. Note that arbitrary thresholds for detecting change were employed; further analyses are required to more rigorously evaluate the variability in IBIs and other results to detect actual trends. Future survey results will provide the information needed to establish levels at which a drop in indicator values signifies a real decrease in stream quality, rather than simply a change owing to natural variability.

In statistical evaluations of the Ohio fish IBI (Fore et al. 1994), the effects of temporal variability and measurement error were small, and the IBI was found to be effective in detecting differences among site conditions. In Maryland, further analysis may be useful to investigate IBI variability, an issue that will be important as these ecological indicators are used to guide management decisions. Ideally, a statistical sampling design would be employed to select a sample of site replicates allowing quantification of temporal (within index periods and across years) and spatial variability.

While the MBSS does not yet provide extensive data to evaluate year-to-year variability in indicator values, some general conclusions can be drawn. First of all, year-to-year variability in important parameters was generally not statistically significant in any of the three resampled basins. Perhaps more importantly, interannual variation in these parameters did not appear to correspond to differences in amounts of annual precipitation. The large amount of rainfall in 1996 did not result in predictably lower (or higher) values for any of the parameters examined, except perhaps for benthic IBI scores in the Patapsco basin. Other possible explanations for the relatively small year-to-year differences that were observed include (1) a general change over time (which could only be addressed by long-term monitoring of basin conditions) and (2) differences in locations of the randomly-selected sites sampled in the two years. One option for distinguishing temporal trends in MBSS data is to design a future sampling component that targets a set of fixed stations for sampling in multiple years. The evaluation discussed above indicates that interannual variability among sampling years in the 1995-1997 MBSS did not significantly influence the composite three-year results. Therefore, no adjustments were made among all basins sampled in different years. Where appropriate, however, results from each year are reported separately for basins sampled twice.

11 RELATIVE CONTRIBUTIONS OF STRESSORS AND THEIR CUMULATIVE IMPACT

The results of the 1995-1997 Maryland Biological Stream Survey (MBSS or Survey) can help answer important management questions about the relative impacts of different stressors on streams as well as diagnose which are acting on individual sites. MBSS results may be used to evaluate both the extent of occurrence of stressors (estimated as the percentage of stream miles having evidence of a particular stress) and the severity of their impacts (based on their relationships with the fish IBI and other biological indicators). While the previous chapters explored the extent of individual stressors and their effects on stream biological communities, this chapter begins to analyze the relative contribution of each stressor and their cumulative impact on stream degradation in Maryland.

11.1 EXTENT OF OCCURRENCE OF MAJOR STRESSORS

Across all basins sampled in the 1995-1997 MBSS, the extent of occurrence of seven major stressors was compared: urban and agricultural land use, nutrients, physical habitat degradation, lack of riparian vegetation, acidic deposition, and acid mine drainage (AMD). The associations between each stressor and IBI scores were examined to determine the value at which each stress was having a significant effect. For the purpose of this analysis, the following thresholds were used to define the presence of a particular stressor:

- Urban land use: > 25% of catchment area
- Agricultural land use: > 75% of catchment area
- Nutrients: nitrate-nitrogen concentration > 7.0 mg/l
- Physical habitat degradation: combined rating of very poor or poor for the Physical Habitat Index (see Chapter 6)
- Lack of riparian vegetation: local riparian buffer width of 0 meters
- Acidic deposition: ANC < 200 μeq/l and water chemistry indicative of atmospheric deposition as a source of acidic materials (see Chapter 7)
- Acid mine drainage: ANC < 200 μeq/l and water chemistry indicative of AMD as a source of acidic materials (see Chapter 7)

Sites affected by both AMD and acidic deposition were included in both estimates. Some important stressors, such as migration barriers, flow reductions, and temperature were not included in this comparison. For selected stressors, the thresholds were chosen to approximate the level at which impacts would occur in most situations. However, some biota may be impacted at much lower levels (e.g., data indicate that brook trout are affected by even lower levels of urban development).

Figure 11-1 shows a ranking of major stressors and their extent of occurrence across all basins sampled in the 1995-1997 MBSS. The most extensive source of stress was physical habitat degradation, which affected an estimated 52% of stream miles. Riparian vegetation was lacking from 28% of stream miles. Agricultural land uses were influential at 17% of stream miles, while urban land use was a potential stress at 12% of stream miles. Nutrient concentrations were high in 5% of stream miles statewide. Acidic deposition affected an estimated 21% of stream miles, while AMD affected 3% of stream miles. While the spatial extent of AMD is relatively small throughout the state, its severity may be great. If not mitigated, extreme acidification can prevent a stream from supporting any aquatic life. In contrast, physical habitat degradation is widespread, but its effects on more tolerant species are often minimal.

Results specific to each basin show that the prevalence of different stressors varies across the state (Figure 11-2). Low physical habitat quality appears to be a problem in all basins. Urbanization is most prevalent in the Patapsco and Potomac Washington Metro basins. Agriculture and nutrient concentrations are most important in the Middle Potomac basin. The lack of riparian vegetation is most widespread in the Patapsco and Middle Potomac basins. AMD and acidic deposition are important sources of stream degradation in the North Branch Potomac and Youghiogheny basins, where urban and agricultural influences are less important. Acidic deposition also affects areas of eastern and central Maryland. In most cases, the relative priority of stressors affecting stream ecosystems depends on the region considered.

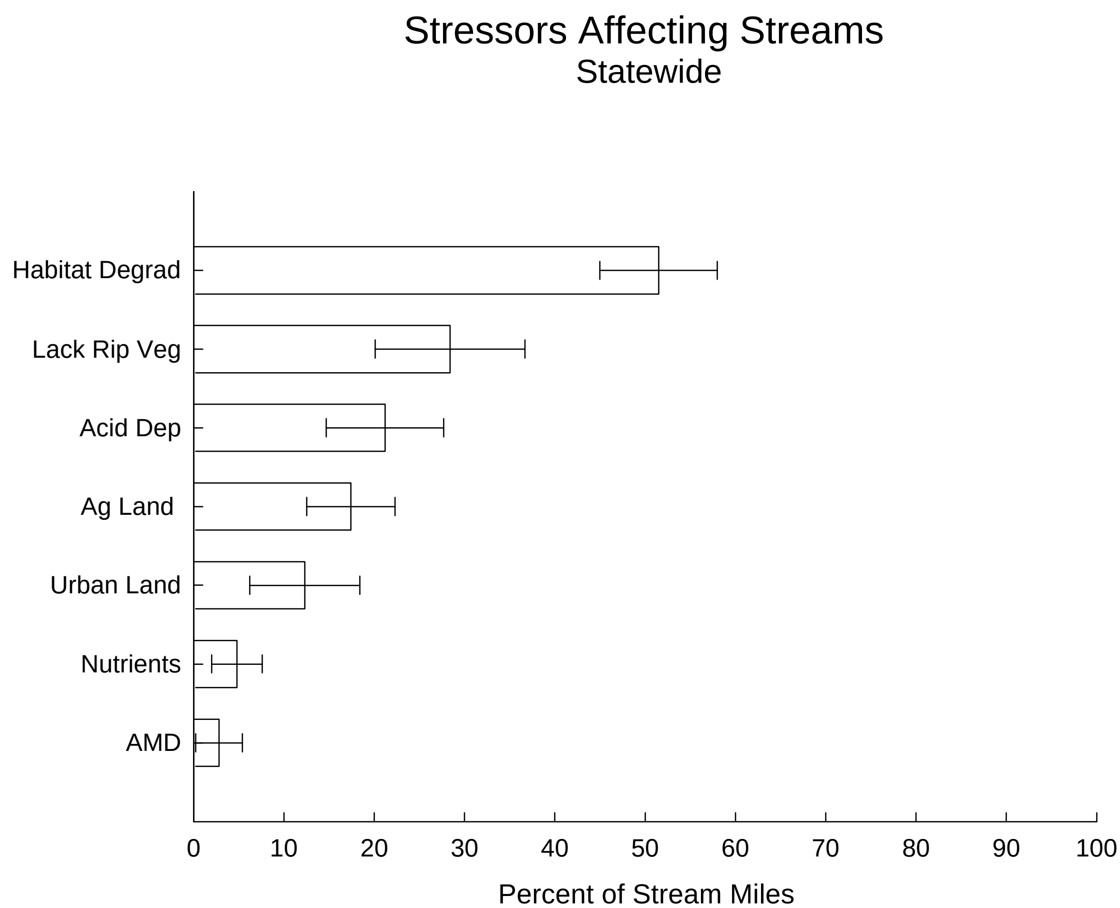


Figure 11-1. Comparative ranking of stressors affecting streams in the 1995-1997 MBSS

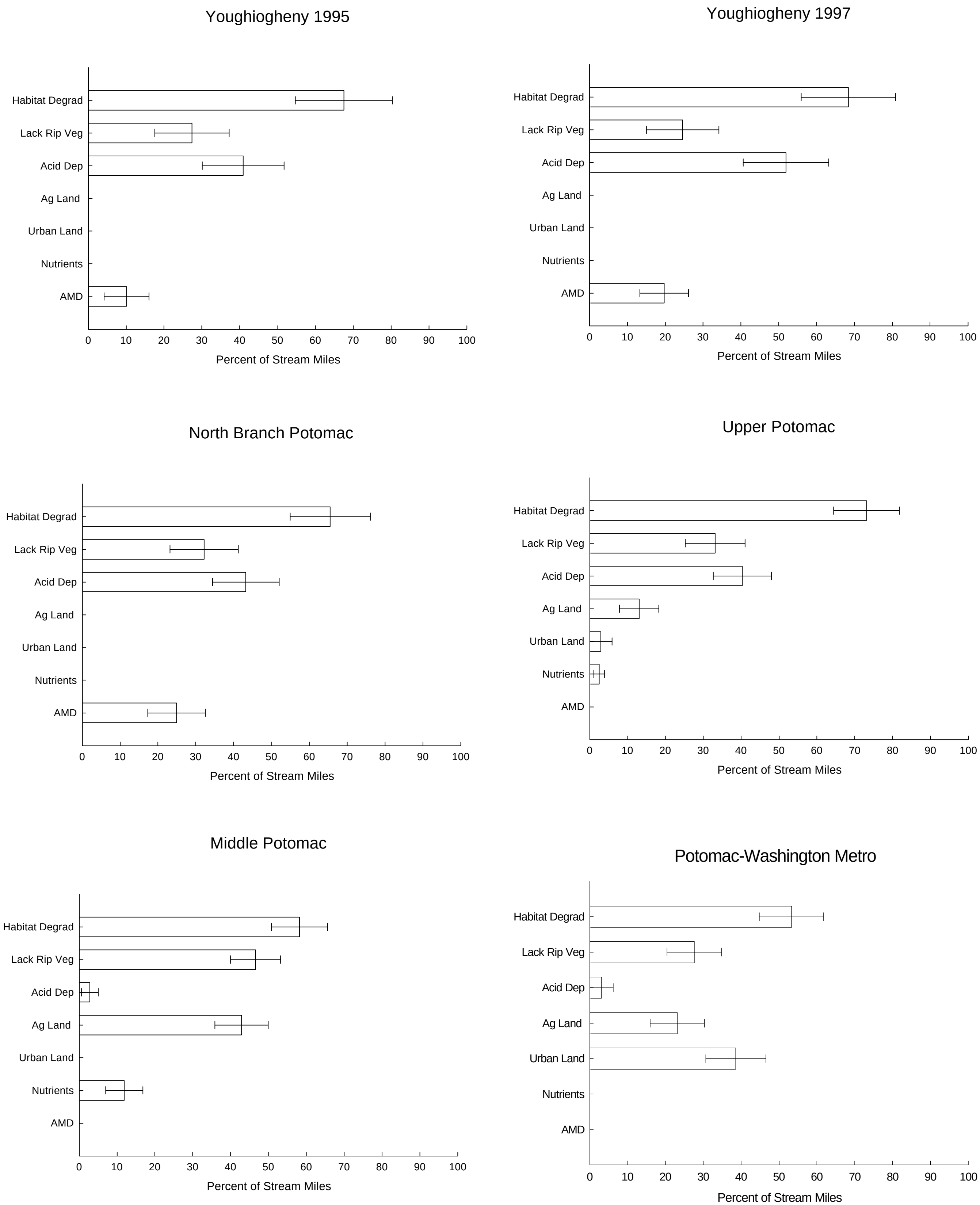


Figure 11-2. Extent of stressors affecting streams for basins sampled in the 1995-1997 MBSS

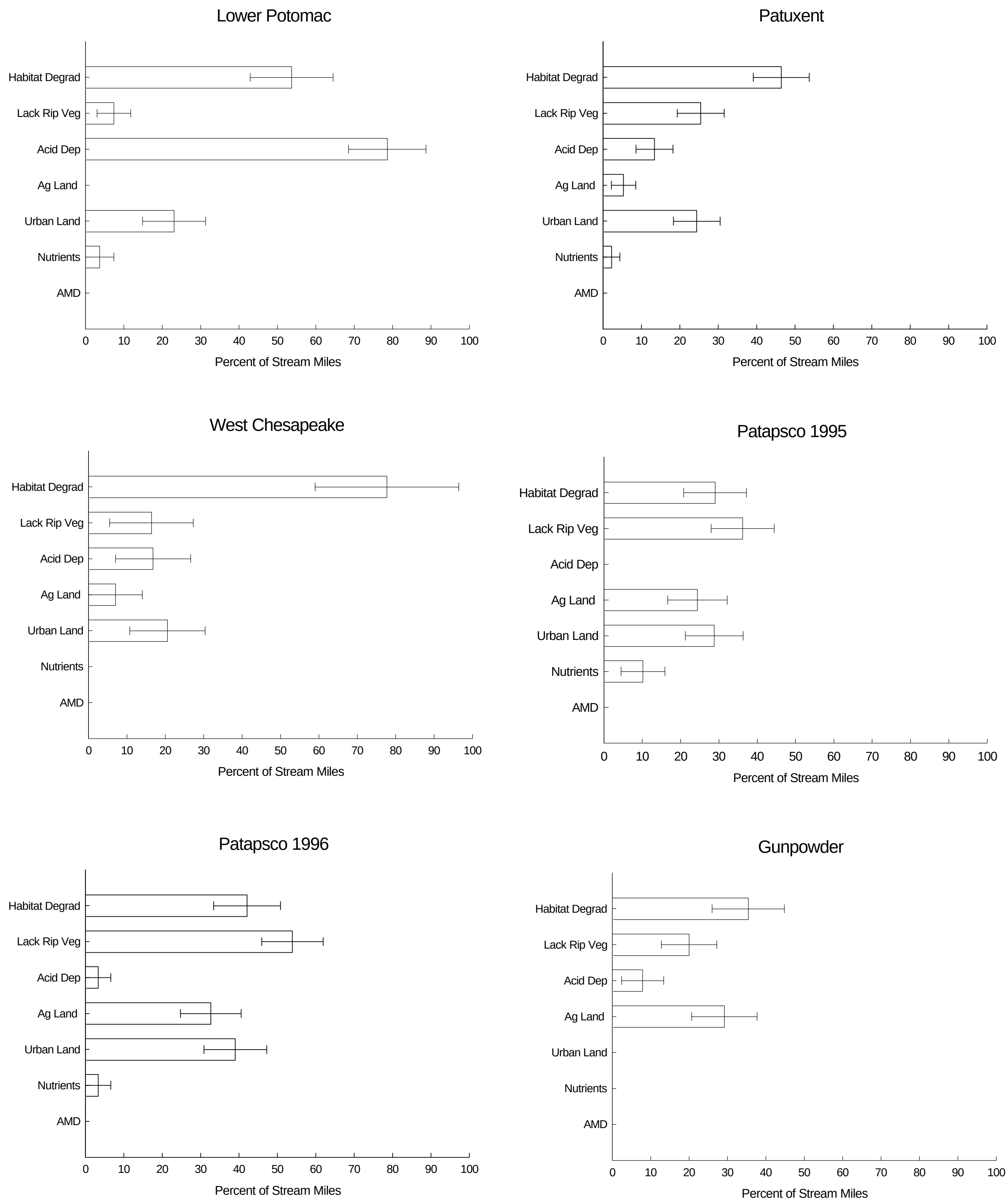
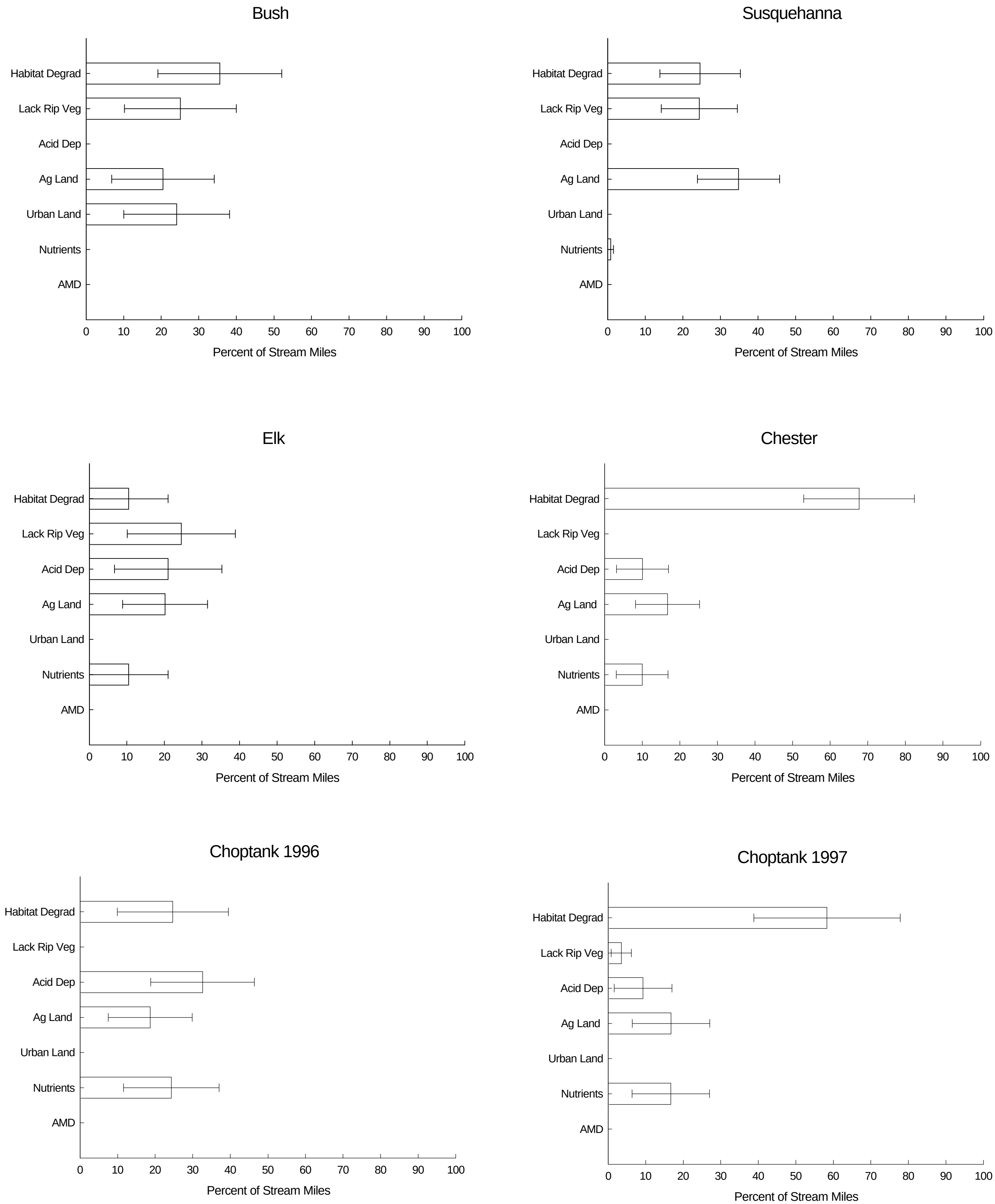


Figure 11-2. Cont'd



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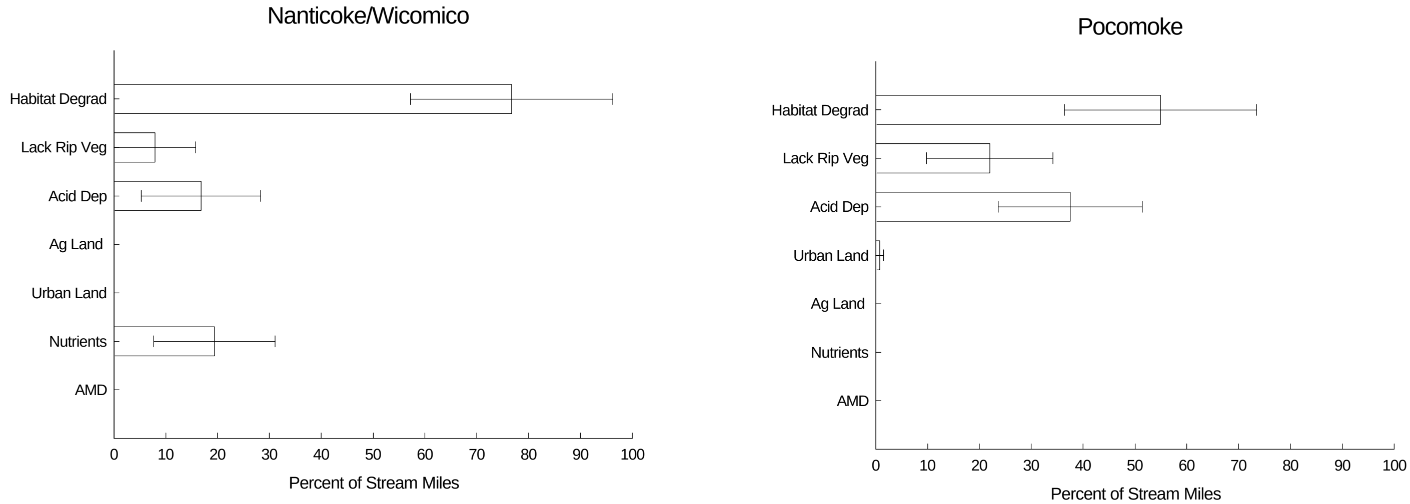

Figure 11-2. Cont'd

Individual stream sites are often affected by more than one stressor. Using the seven categories of stressors listed above, the number of stressors at each of the 905 summer sampleable sites (for which complete physical habitat data were available) were tallied. Overall, 72% of the sites sampled in the 1995-1997 MBSS were impacted by at least one of these seven stressors. Thirty-eight percent were affected by one stressor and 34% by two or more stressors (27% by two stressors, 6% by three stressors, and 1% by four stressors). The relatively frequent occurrence of multiple stressors naturally led to an investigation of the cumulative effect of these stressors upon the biological integrity of Maryland streams.

11.2 EFFECTS OF MULTIPLE STRESSORS ON IBIs

The conclusions in Section 11.1 are further supported by multiple regression analysis using each of the IBIs as the response variable and the seven stressors as indicator variables. The numerical values for the percentage of urban land use, percentage of agricultural land use, nitrate-nitrogen concentration, physical habitat degradation, and riparian buffer width were used in the model; acidic deposition and AMD were represented by categorical values based on the presence of that stressor. Statewide, fish IBI scores decreased significantly with an increase in urban land use, nitrate-nitrogen concentration, and the presence of AMD. Fish IBI scores increased significantly with an increase in agricultural land use and with improved physical habitat quality. Neither the width of riparian vegetation (as measured within the 75-m segment) nor the presence of acidic deposition were significant factors for explaining variation in fish IBI scores statewide.

The multivariate analysis was also conducted for each individual basin. Stressors that were significant in each basin are listed in Table 11-1. Poor physical habitat quality significantly affected fish IBI in 13 of the 17 basins sampled. No significant effect was observed in the West Chesapeake, Patapsco, Elk, and Choptank basins. The percentage of urban land was significant in the Middle Potomac, Potomac Washington Metro, and Patapsco basins. The percentage of agricultural land was significant in the Middle Potomac, West Chesapeake, Gunpowder, Chester, Choptank, and Nanticoke/Wicomico basins. Nutrients were significant in the Middle Potomac basin. Acidic deposition was significant in the North Branch Potomac and Choptank basins. AMD was significant in the North Branch Potomac basin. In combination with the other factors in the model, the absence of local riparian vegetation was not a significant stressor upon fish IBI in any of the basins sampled. This may be a result of the fact that physical habitat quality and nutrient concentrations (which often accompany riparian vegetation loss) are better indicators of stream degradation. Also, our local measure of riparian buffer width adequately represent the role of riparian vegetation, as it does not assess conditions upstream of the site. In fact, other analysis of Survey data has demonstrated a clear link between fish IBI scores and upstream riparian condition at the watershed level (Roth et al. 1998). None of the seven stressors were significant in the Elk basin. This may reflect the relatively good condition of streams in this basin with 38% of stream miles rated good and no stream miles rated very poor.

Table 11-1. Stressors significantly affecting biotic integrity (based on multiple regression models of stressors against fish IBI scores), by basin for the 1995-1997 MBSS

	% Urban Land	% Agricultural Land	Nutrients	Physical Habitat Quality	Acid Mine Drainage	Acid Deposition	Riparian Buffer Width
Youghiogheny				X			
North Branch Potomac				X	X	X	
Upper Potomac				X			
Middle Potomac	X	X	X	X			
Potomac Washington Metro	X			X			
Lower Potomac				X			
Patuxent				X			
West Chesapeake		X					
Patapsco	X						
Gunpowder		X		X			
Bush				X			
Susquehanna				X			
Elk							
Chester		X		X			
Choptank		X				X	
Nanticoke/Wicomico		X		X			
Pocomoke				X			

It is likely that stressors significantly affecting fish IBI are most deleterious where a stressor is present in a large percentage of stream miles. Adverse effects may also be important in basins where a particular stressor has a severe impact on fish IBI scores, but is present in only a small percentage of stream miles. Physical habitat degradation was the prevalent stressor in 11 of the basins sampled. It had a significant impact upon fish IBI scores in 10 of these basins: the Youghiogheny, North Branch Potomac, Upper Potomac, Middle Potomac, Potomac Washington Metro, Patuxent, Gunpowder, Bush, Nanticoke/Wicomico, and Pocomoke basins. The percentage of urban land use in the catchment area was a significant stressor in the two basins with the most stream miles draining greater than 25% urban land: the Potomac Washington Metro and Patapsco basins. Nitrate-nitrogen was a significant stressor in the Middle Potomac basin, even though it was only present at elevated levels in 12% of the stream miles in that basin. This result indicates that nitrogen levels greater than 7.0 mg/l may have a drastic impact on fish IBI, even if the problem is not widespread. In the North Branch Potomac basin, acidic deposition and AMD were both present in greater than 25% of the stream miles. In this basin, both acid sources had a significant effect upon fish IBI.

Statewide, benthic IBI scores decreased significantly with an increase in urban land use and with the presence of AMD. Benthic IBI scores increased significantly with improved physical habitat quality and increased riparian buffer width. Surprisingly, benthic IBI scores also increased with the presence of acidic deposition. As discussed in Chapter 9, both the benthic IBI and the incidence of acidic deposition increased with the amount of forested land use in a watershed. Thus, it is expected that benthic IBI and acidic deposition would be positively correlated. Neither the percentage of agricultural land or the concentration of nitrogen were significantly correlated with the fish IBI in the multiple regression model.

Stressors that were significantly correlated to the benthic IBI are listed in Table 11-2. None of the seven stressors were significantly correlated to benthic IBI in nine of the basins sampled: the Upper Potomac, Middle Potomac, Lower Potomac, West Chesapeake, Gunpowder, Susquehanna, Elk, Nanticoke/Wicomico, and Pocomoke. Physical habitat quality was significantly related to the benthic IBI only in the Patapsco and Chester basins (a marked contrast to this parameter’s strong relationship to the fish IBI in many

Table 11-2. Stressors significantly affecting biotic integrity (based on multiple regression models of stressors against benthic IBI scores), by basin for the 1995-1997 MBSS							
	% Urban Land	**% Agricultural Land**	**Nutrients**	**Physical Habitat Quality**	**Acid Mine Drainage**	**Acid Deposition**	**Riparian Buffer Width**
Youghiogheny					X		
North Branch Potomac	X				X		
Upper Potomac							
Middle Potomac							
Potomac Washington Metro	X						
Lower Potomac							
Patuxent	X						
West Chesapeake							
Patapsco	X			X			
Gunpowder							
Bush	X						
Susquehanna							
Elk							
Chester				X			X
Choptank							X
Nanticoke/Wicomico							
Pocomoke							

basins). The percentage of urban land was significantly related to the benthic IBI in the North Branch Potomac, Potomac Washington Metro, Patuxent, Patapsco, and Bush basins. Riparian buffer width was significantly correlated to the benthic IBI in the Chester and Choptank basins. As with the fish IBI, the benthic IBI showed a significant correlation to AMD in the Youghiogheny and North Branch Potomac basins.

11.3 INFLUENCE OF STRESSORS AT INDIVIDUAL SITES

MBSS data can be used to detect stream degradation at individual sites and to identify the stressors contributing to degradation. This is relevant to State efforts to identify streams in need of restoration and to identify impaired waters as candidates for 303(d) listing. It should be noted that although the random statewide design provides accurate estimates of the number of stream miles that are degraded, only those sites that have actually been sampled have the potential to be identified here as degraded.

Analyzing for the effects of stressors at particular sites is a multi-step process that uses biological, physical, and chemical data. In this analysis, the fish IBI and benthic IBI were first used to identify candidate degraded sites (e.g., fish IBI or benthic IBI rating of poor to very poor). Then, field observations and site-specific data on water chemistry, watershed land use, and physical habitat conditions were used to determine the stressors (i.e., human activities) likely causing degradation. Finally, site-specific data were examined to rule out natural factors that may contribute to low indicator scores. Note that analysis was based solely on the MBSS data sets. Examining ancillary information, including previous studies and local knowledge of site conditions, can be a useful additional stage to better understand the factors affecting individual streams.

For the 1995-1997 MBSS, 203 sites rated either poor or very poor for both the fish and benthic IBIs. Another 175 sites

rated poor or very poor for the benthic IBI and either fair or good for the fish IBI, while 73 sites rated poor or very poor for the fish IBI and either fair or good for the benthic IBI. There were 88 sites that were rated poor or very poor for the benthic IBI and were not rated for the fish IBI. Altogether, there were a total of 539 sites scrutinized for potential stressors. For each site, physical and chemical data were examined and compiled into a matrix. Parameter values above or below the following threshold levels were considered as possible indicators of stress:

- Physical Habitat Index score < 42 (poor to very poor)
- Hilsenhoff Index > 6.0 (poor to very poor)

- Urban land use > 25% of catchment area
- Agricultural land use > 75% of catchment area
- Spring pH < 5
- Summer pH < 5
- ANC < 200 μeq/l
- Nitrate-nitrogen > 2 mg/l
- DO < 5 ppm
- Sulfate > 24 mg/l
- DOC > 8.0 ppm
- Presence of a surface mine
- Presence of a landfill
- Channelization
- Presence of a storm drain
- Presence of effluent discharge
- Presence of a beaver pond
- Instream habitat score < 11 (out of 20 points)
- Epifaunal substrate score < 11
- Velocity/depth diversity score < 11
- Pool/glide/eddy quality score < 11
- Riffle/run quality score < 11
- Channel alteration score < 11
- Bank stability score < 11
- Embeddedness > 75%
- Channel flow status < 30%
- Shading < 30%
- Riparian buffer width < 15 m

Remoteness score < 11

- Aesthetics score < 11
- Maximum depth < 20 cm
- Average thalweg depth < 20 cm

Also included in the matrix are several variables that provided additional information on site conditions and location. These variables include:

- Catchment area (acres)
- Whether any fish were captured at the site
- Whether the site is a brook trout stream
- Whether the site is a blackwater stream
- Acid source, if present
- Riparian buffer land type
- Land use adjacent to riparian buffer
- Type of stream blockage, if present
- Stream name
- Maryland 8-digit watershed code
- Watershed name
- Latitude and Longitude
- Stream order

A matrix was compiled including these parameters, additional explanatory variables, and locational information for all 539 sites with a fish or benthic IBI score rated as poor to very poor. These results are reported in Appendix F.

12 BIODIVERSITY

Earlier in this report, the extent and condition of certain organism groups (fish, benthic macroinvertebrates, etc.) were presented under the headings of Characterization (Chapter 4) and Biological Assessment (Chapter 5). While these results do a good job of describing the general quality of Maryland's nontidal streams, they do not capture the full variety of aquatic biota in the State, i.e., its biodiversity. Specifically, although the concept of biological integrity (as embodied in the Index of Biotic Integrity (IBI) results of Chapter 5) attempts to capture the central premise of biodiversity (i.e., the natural state of biological communities), use of the IBI alone cannot describe or preserve all components (e.g., rare species and unusual ecosystems) of biodiversity (Southerland 1998). Therefore, this chapter draws upon the data collected in the 1995 - 1997 Maryland Biological Stream Survey (MBSS or the Survey) to address the following additional components of biodiversity: species richness and distribution, rare species, vulnerable fish populations, non-native fish species, fish hybrids, and high integrity streams. A discussion of approaches to identifying centers, or "hotspots," of freshwater biodiversity using MBSS data is presented in Southerland et al. (1998, 1999).

By general scientific consensus, biodiversity is defined as (Noss and Cooperrider 1994)

> *...the variety of life and its processes. It includes the variety of organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning, yet ever changing and adapting.*

Biodiversity can be conserved at four scales (levels of organization): genetic, species, ecosystem, and landscape (OTA 1987, CEQ 1993). The primary conservation goals at the larger scales are (1) representing all native ecosystems in a network of protected areas and (2) maintaining complete, unfragmented environmental gradients (Noss and Cooperrider 1994).

Allan and Flecker (1993) stated that "from the standpoint of biological diversity, rivers and streams are both rich in species and severely imperiled." Indeed, aquatic species are among the most endangered in the United States with a reported 28% of amphibian species, 34% of fish, and 73% of unionid mussels ranked as extinct to rare (Master 1990, Williams et al. 1989). The primary threats to conserving biodiversity in running water systems are habitat degradation and invasions of non-native species (Allan and Flecker 1993). Aquatic resources make up an important part of Maryland's biological diversity and the Ecosystem Council of Maryland DNR (1996) recognizes that conserving biodiversity is critical to its mission of managing natural resources.

To date, the ability to address aquatic biodiversity nationally or regionally has been limited by an inadequate knowledge base (Allan and Flecker 1993). Information in the MBSS can help environmental decision-makers address the conservation of biodiversity. The species occurrences in this report are statewide and represent the most comprehensive geographic data collected in a single survey. They do not, however, reflect the species occurrences or community distributions available from the Maryland Natural Heritage Program or other information sources. At present, the Survey does not address genetic diversity, nor does it define the ecosystem or landscape types found in Maryland. On the other hand, it contains detailed information on the distribution and abundance of aquatic species (especially fish) and the communities in which they reside (as measured by species composition at stream sites). The occurrence of high species numbers and rare species can be described by sample site, watershed, or river basin. Ultimately, this information may help Maryland DNR meet its goal of protecting and restoring natural ecosystems with enough native components to sustain themselves over time.

12.1 SPECIES RICHNESS AND DISTRIBUTION

The most easily understood component of biodiversity is species diversity, i.e., the number of species and how they are distributed geographically. The total number of species (species richness) is a useful way of characterizing the natural diversity of taxonomic groups in a given area. Geographically restricted species are often at greatest risk and warrant priority conservation action. The Survey provides an especially good description of the number of fish species in each sampled stream and all river basins; species and taxa numbers are less accurate (because appropriate habitats were less thoroughly searched) for benthic macroinvertebrates, amphibians and reptiles (herpetofauna), mussels, and aquatic vegetation. Nonetheless, comparisons among these different assemblages provide useful insights. The results below focus on the species or taxa richness of each river basin for these five assemblages. In addition, the richness and distribution of each assemblage across three major geographic regions (Highlands, Eastern Piedmont, and Coastal Plain) are shown. Except where noted (i.e., core MBSS sampling only), species distributions include supplemental MBSS sampling that adds two fish species (banded darter and Atlantic menhaden) and extends the range of others (see Table 4-1 in Chapter 4).

Finer-scale presentations of native fish species richness in smaller watersheds (limited by small sample number in some watersheds) and stream sites are shown in selected figures. Analysis of these results (using only fish species captured in the core MBSS sampling) indicates that a relatively small subset of the Maryland 8-digit watersheds (11 or 8% of the 138 watersheds in Maryland) captures all the fish species sampled by the Survey and that a single watershed, the Anacostia, captures 45% of the species (Southerland et al. 1999). Similar figures of taxa richness patterns for benthic macroinvertebrates and amphibians and reptiles are included in Southerland et al. (1998).

12.1.1 Fish

The total complement of fish species sampled by the Survey is not exhaustive (it misses about half of the rarest species listed by the Maryland Natural Heritage Program), but it provides the most accurate species richness numbers to date for all parts of the State. Figure 12-1 illustrates the number of native fish species present at each core MBSS sample stream site. The most species-rich sites are in the central part of the State, but are scattered over more than one-third of Maryland. It should be noted that these species numbers are a combination of natural species richness and impacts of anthropogenic activities.

Among the 17 river basins in Maryland, the number of all fish species (native and non-native) sampled ranged from 28 in the Youghiogheny basin to 57 in the Patuxent basin (Figure 12-2). Only three fish species (largemouth bass, bluegill, and pumpkinseed) were present in all 17 river basins. None of these statewide ranges are natural; largemouth bass and bluegill were introduced to the Chesapeake Bay drainage and pumpkinseed was introduced to the Youghiogheny basin. On the other end of the spectrum, six basins (Youghiogheny, Lower Potomac, Patuxent, Susquehanna, Chester, and Pocomoke) contained one or two fish species (including johnny darter, striped shiner, flier, shorthead redhorse, stripeback darter, banded darter, Atlantic menhaden, and longnose gar) unique to that basin. Therefore, most of the 85 fish species collected were found in more than one, but not all, river basins in Maryland.

When the distribution of fish species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, 51 occurred in all three regions and less than 10 are unique to any one region (Figure 12-2). In no case did a fish species occur in the Highlands and Coastal Plain, but not in the Piedmont. Table 4-1 and the discussion in Chapter 4 describe the distributions of individual fish species in more detail.

12.1.2 Benthic Macroinvertebrates

Information on the taxonomic diversity of benthic macroinvertebrates was enhanced for this statewide report by identifying this component of the aquatic community to the genus, or lowest practicable taxon, level. Although previous analyses at the family level were useful, genera were used in this report because they more closely describe the ecological roles and contribution to biodiversity of benthic macroinvertebrates. It should be noted that the presence of taxa at each sample site only reflects those captured in the 100-organism subsamples. While subsamples effectively characterize the benthic macroinvertebrate communities in these streams, rare taxa were undoubtedly missed at many sites.

Among the 17 river basins in Maryland, the number of all benthic macroinvertebrate taxa sampled ranged from 83 in the Elk and Bush basins to 190 in the Lower Potomac basin (Figure 12-3). Only 14 benthic macroinvertebrate taxa were present in all 17 river basins. On the other end of the spectrum, the Bush basin did not contain any benthic macroinvertebrate taxa unique to that basin. In no basin did the percentage of taxa unique to the basin exceed 10%. Therefore, most of the 346 benthic macroinvertebrate taxa collected were found in more than one, but not all, river basins in Maryland.

When the distribution of benthic macroinvertebrate taxa among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, the majority (122) occurred in all three regions and less than 30 are unique to any one region (Figure 12-3).

12.1.3 Amphibians and Reptiles

The amphibian and reptile species collected by the Survey are a sample of those species that reside in streams and their riparian zones. These amphibian and reptiles are a subset of the larger herpetofauna of the State that include many primarily terrestrial species. The 45 species collected

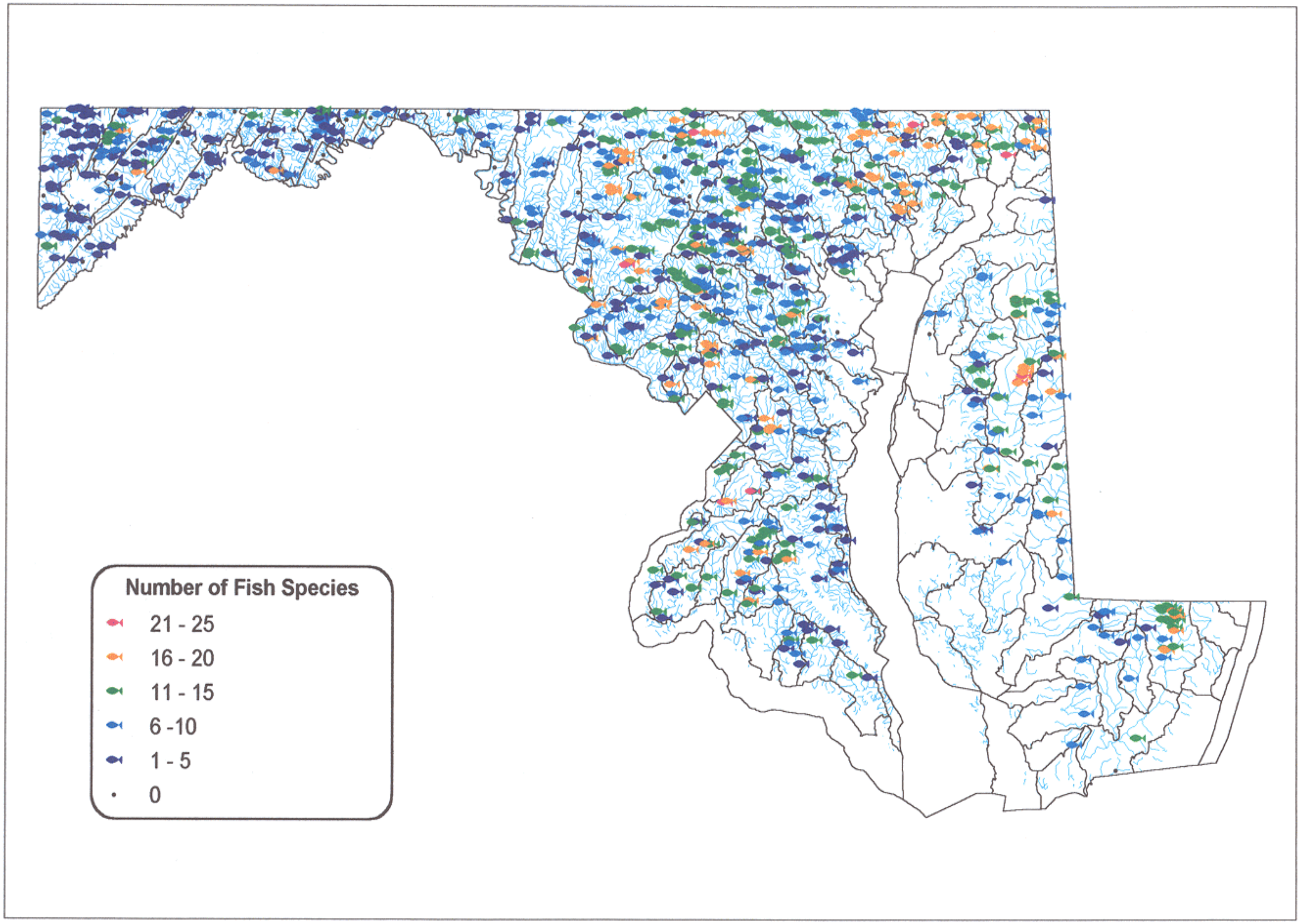

Figure 12-1. Native fish species richness by site for the 1995 - 1997 MBSS

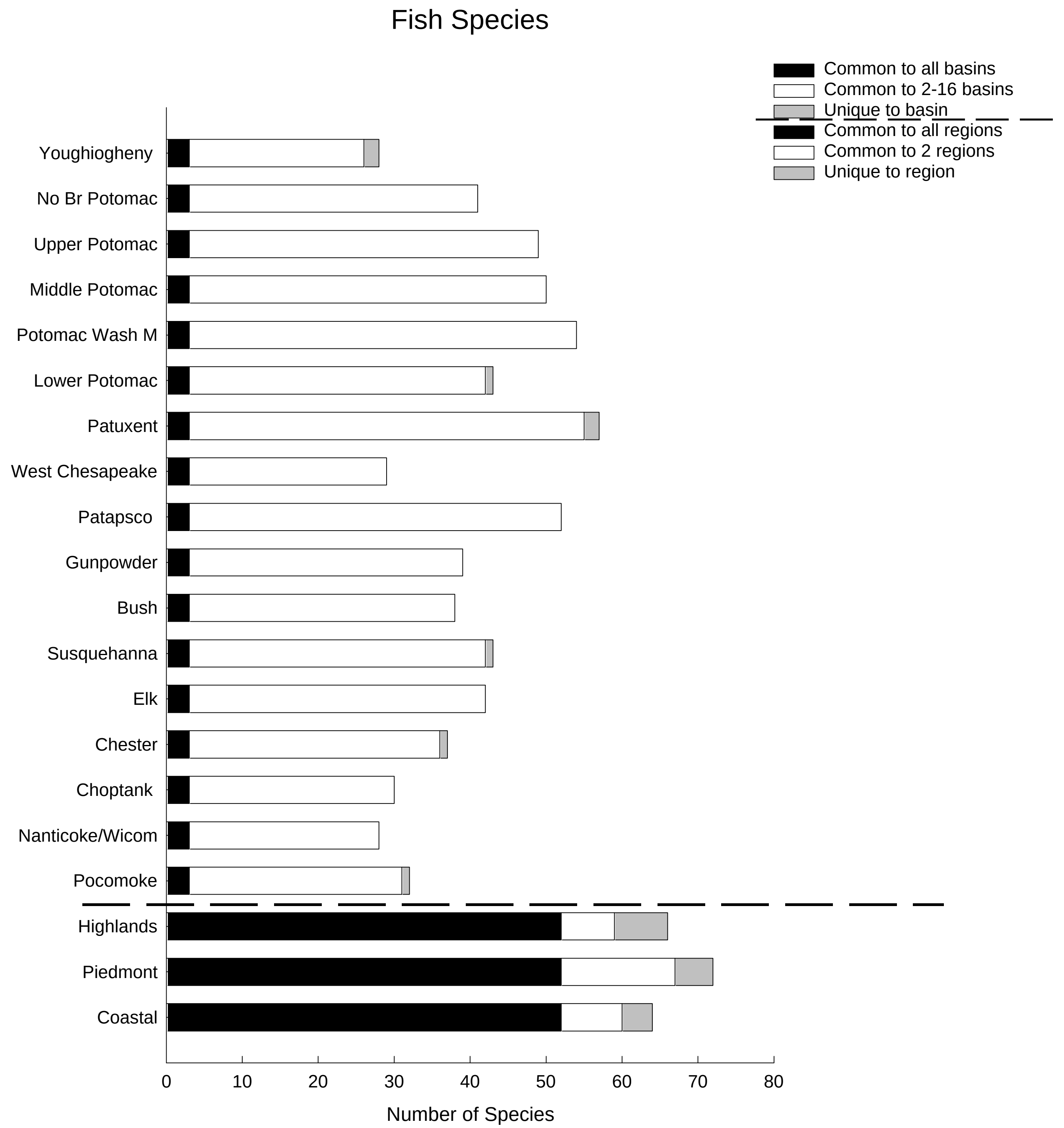

Figure 12-2. Fish species richness by basin and geographic region for the 1995-1997 MBSS

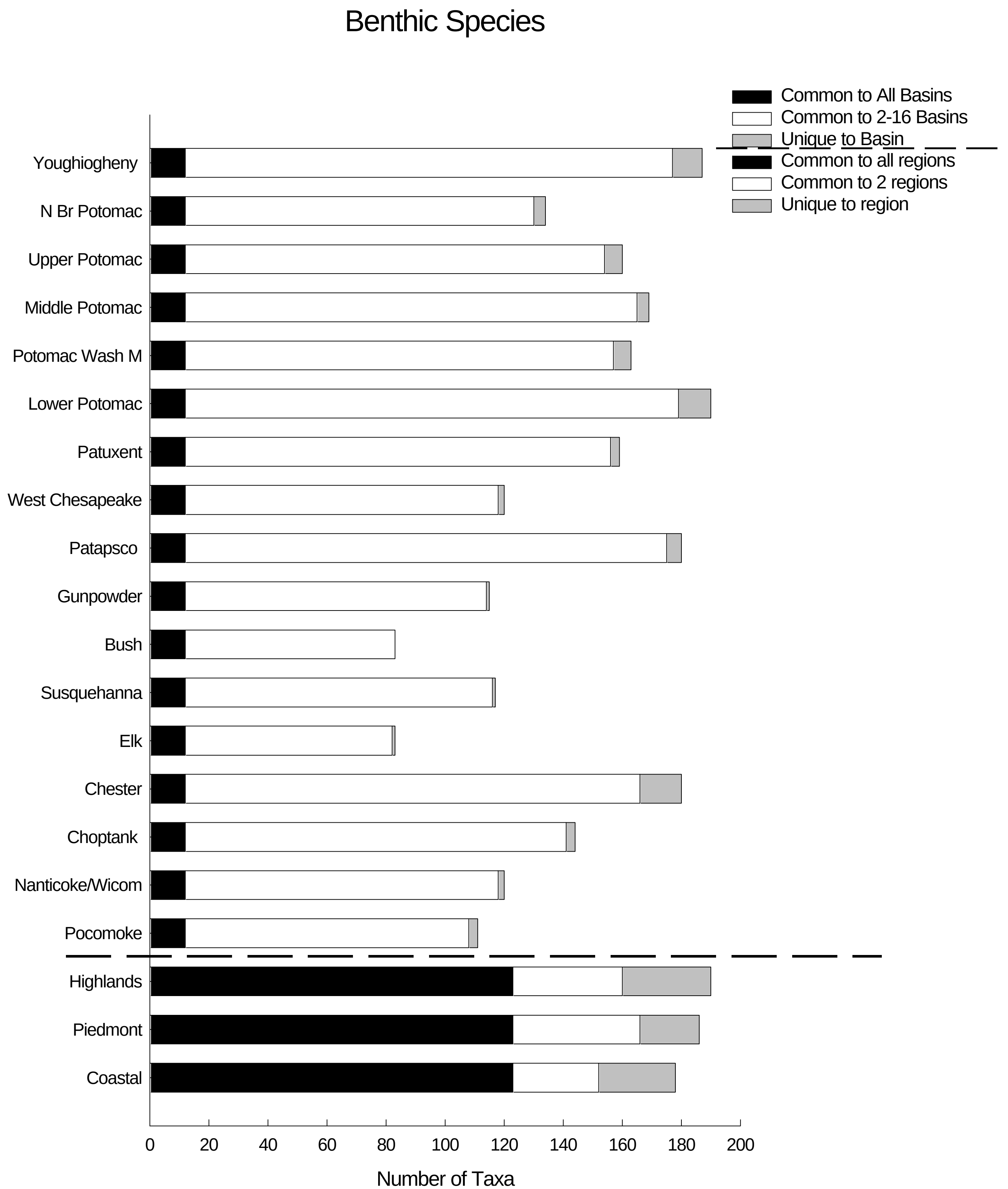

Figure 12-3. Benthic species richness by basin and geographic region for the 1995-1997 MBSS

their riparian zones. These amphibian and reptiles are a subset of the larger herpetofauna of the State that include many primarily terrestrial species. The 45 species collected by the Survey represent 56% of the amphibians and 40% of the reptiles reported by Maryland DNR to exist in the State. Because the Survey focuses on streams and riparian areas, we have looked both at the species richness and distribution of all amphibian and reptile species and those that are dependent on aquatic systems (Figure 12-4). Interestingly, although the number of aquatic-dependent species found is on average 60% less than the total, the pattern of species richness across the three major geographic regions (Highlands, Eastern Piedmont, and Coastal Plain) and the 17 basins is virtually the same. Therefore, the following discussion includes all the amphibian and reptile species sampled by the Survey in 1995 to1997.

In general, the statewide pattern of total amphibian and reptile species richness declines from the western to eastern parts of the State (Figure 12-5). Among the 17 basins in Maryland, the number of all amphibian and reptile species sampled ranged from 9 in the Nanticoke/Wicomico to 26 in the Patuxent. Only two amphibian (green frog and bullfrog) and one reptile (northern water snake) species were present in all 17 basins. At the other extreme, six basins (Youghiogheny, North Branch Potomac, Upper Potomac, Patuxent, Choptank, and Nanticoke/Wicomico) contained one or two amphibian or reptile species (including Jefferson salamander, northern fence lizard, gray treefrog, redbelly turtle, eastern smooth earth snake, rough green snake, and smooth green snake) unique to that basin. Therefore, most of the 45 amphibian and reptile species collected were found in more than one, but not all, river basins in Maryland.

When the distribution of amphibian and reptile species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, 18 occur in all three regions with the number of species unique to one region ranging from 2 in the Coastal Plain to 6 in the Highlands (Figure 12-5). As would be expected (given their different ecological requirements), the species richness patterns for each herpetofaunal organism group vary and are discussed separately below.

Salamander species richness showed the most striking geographic variation; it was highest in the western basins, with 9 to 11 observed species in the Youghiogheny, North Branch Potomac, and Upper Potomac basins (Figure 12-6). The only species unique to a single basin (North Branch Potomac) was the Jefferson salamander (*Ambystoma jeffersonianum*). This species was the only amphibian or reptile found by the Survey that is on the Maryland DNR (1997) listing of state-listed endangered, threatened, or species of special concern.

Frog and toad species richness was fairly evenly distributed across the 17 basins, ranging from four species in three basins to a high of 10 species in the Patuxent basin (Figure 12-7). While most of the 11 species were widespread, the gray treefrog and northern cricket frog were found in only one or two basins (Lower Potomac and Patuxent).

The number of turtle species increased in the more southern basins, ranging from one to five species per basin (Figure 12-8). A terrestrial species, the eastern box turtle, was found in 14 of the basins, while redbelly and spotted turtles were found in only one or two basins (Middle Potomac, Potomac Washington Metro, and Nanticoke/Wicomico).

The number of snake and lizard species declined slightly in eastern basins, ranging from one species in Nanticoke/Wicomico to seven in Upper Potomac (Figure 12-9). The aquatic northern water snake was observed in all 17 basins, while six species were found in only one or two basins.

12.1.4 Mussels

Freshwater mussels in the eastern United States are one of the most imperiled faunas in the nation (Master 1990, Williams et al. 1989). In Maryland, there are 18 species of freshwater unionid bivalves. Two species, eastern elliptio (*Elliptio complanata*) and the eastern floater (*Pyganodon cataracta*) occur most commonly and are the most abundant species. The plain pocketbook (*Lampsilis cardium*) has been introduced into the Potomac River, presumably as a result of fish stocking. Additionally, the Asiatic clam (*Corbicula fluminea*) has been introduced throughout Maryland.

Fourteen species of freshwater unionid mussels are listed as rare or endangered in Maryland (MDNR 1997). The dwarf wedge mussel (*Alasmidonta heterodon*) is listed both as state and federally endangered, while three other species, the triangle floater (*Alasmidonta undulata*), brook floater (*Alasmidonta varicosa*), and green floater *(Lasmigona subviridis*) are listed as state endangered and are candidates for federal listing. Yellow lampmussel (*Lampsilis cariosa*) is considered extirpated in Maryland. Nine other species are listed as rare (Table 12-1). There is also concern about the status of several other species such as the elktoe (*Alasmidonta marginata*), which has not been found in recent years (Karene Motivans, MDNR, personal communication).

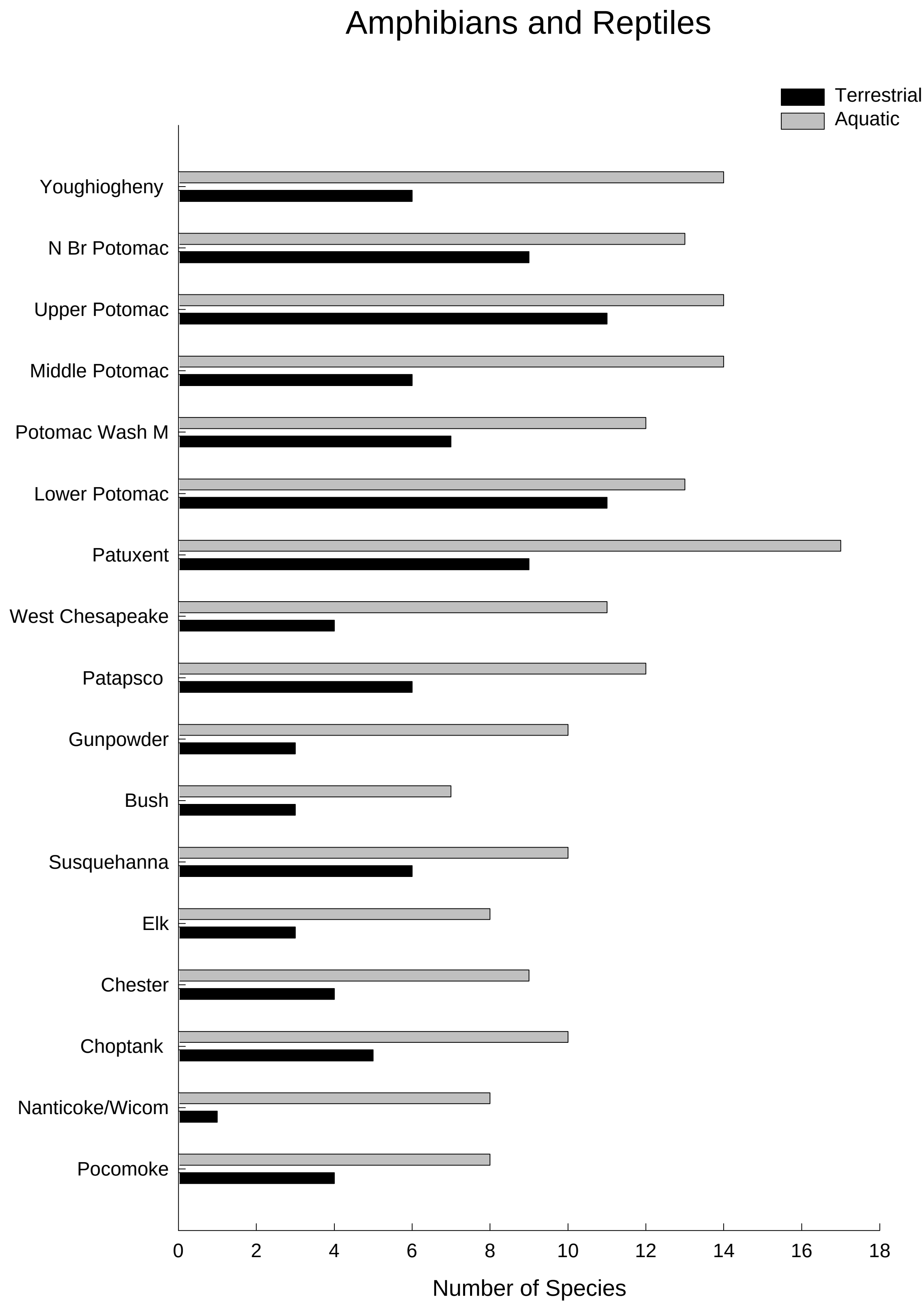

Figure 12-4. Terrestrial and aquatic amphibian and reptile species richness by basin for the 1995-1997 MBSS

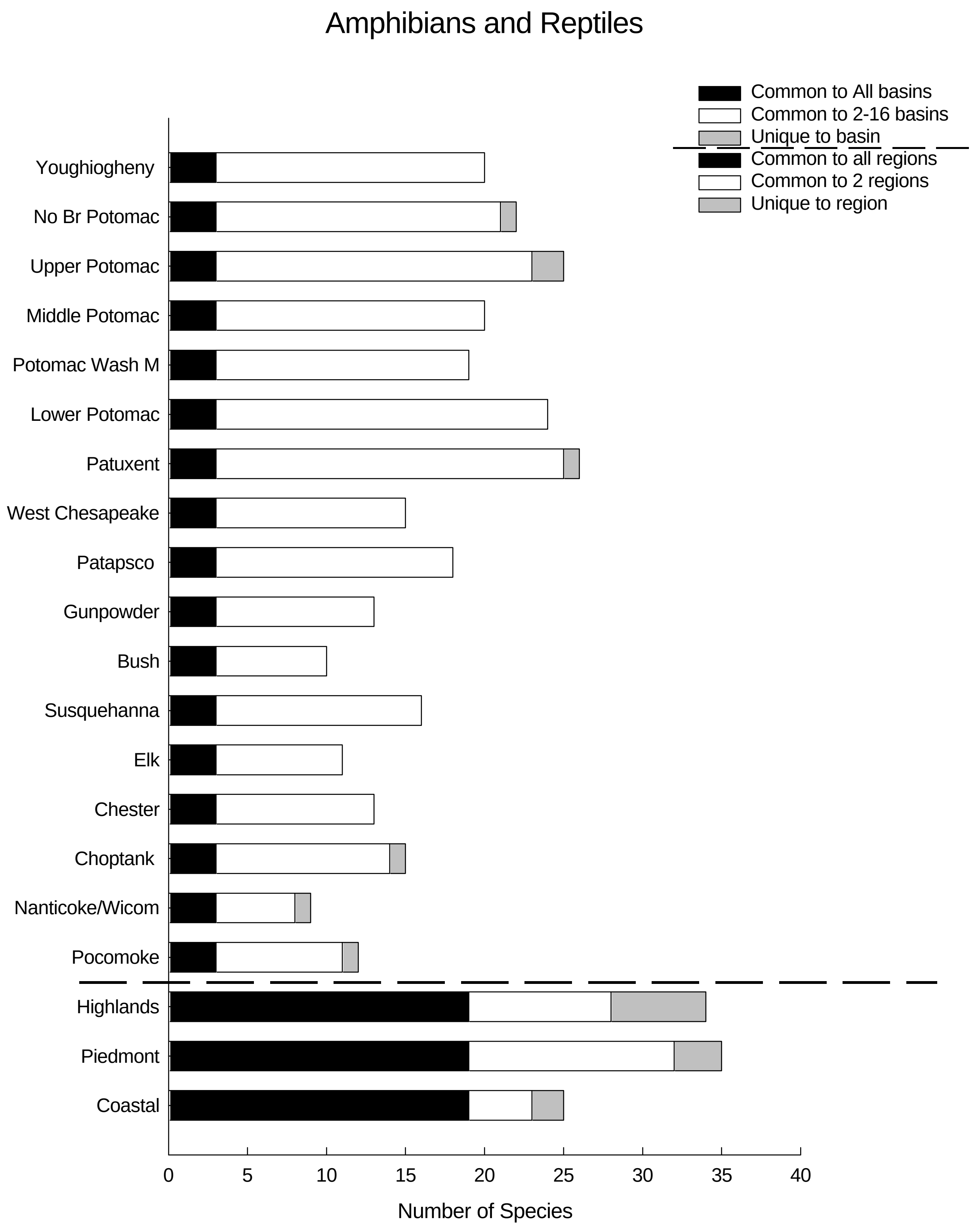

Figure 12-5. Total amphibian and reptile species richness by basin and geographic region for the 1995-1997 MBSS

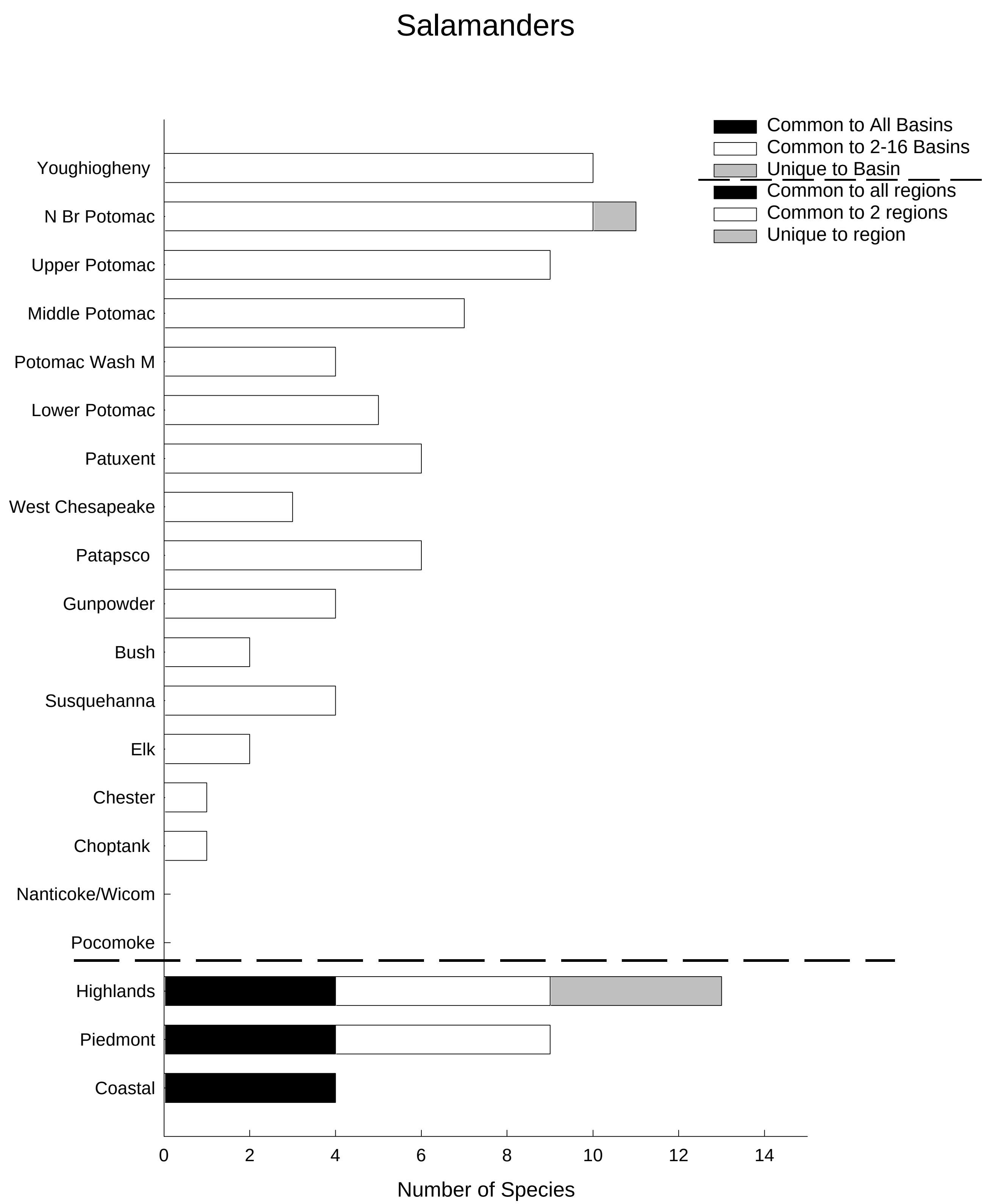

Figure 12-6. Salamander species richness by basin and geographic region for the 1995-1997 MBSS

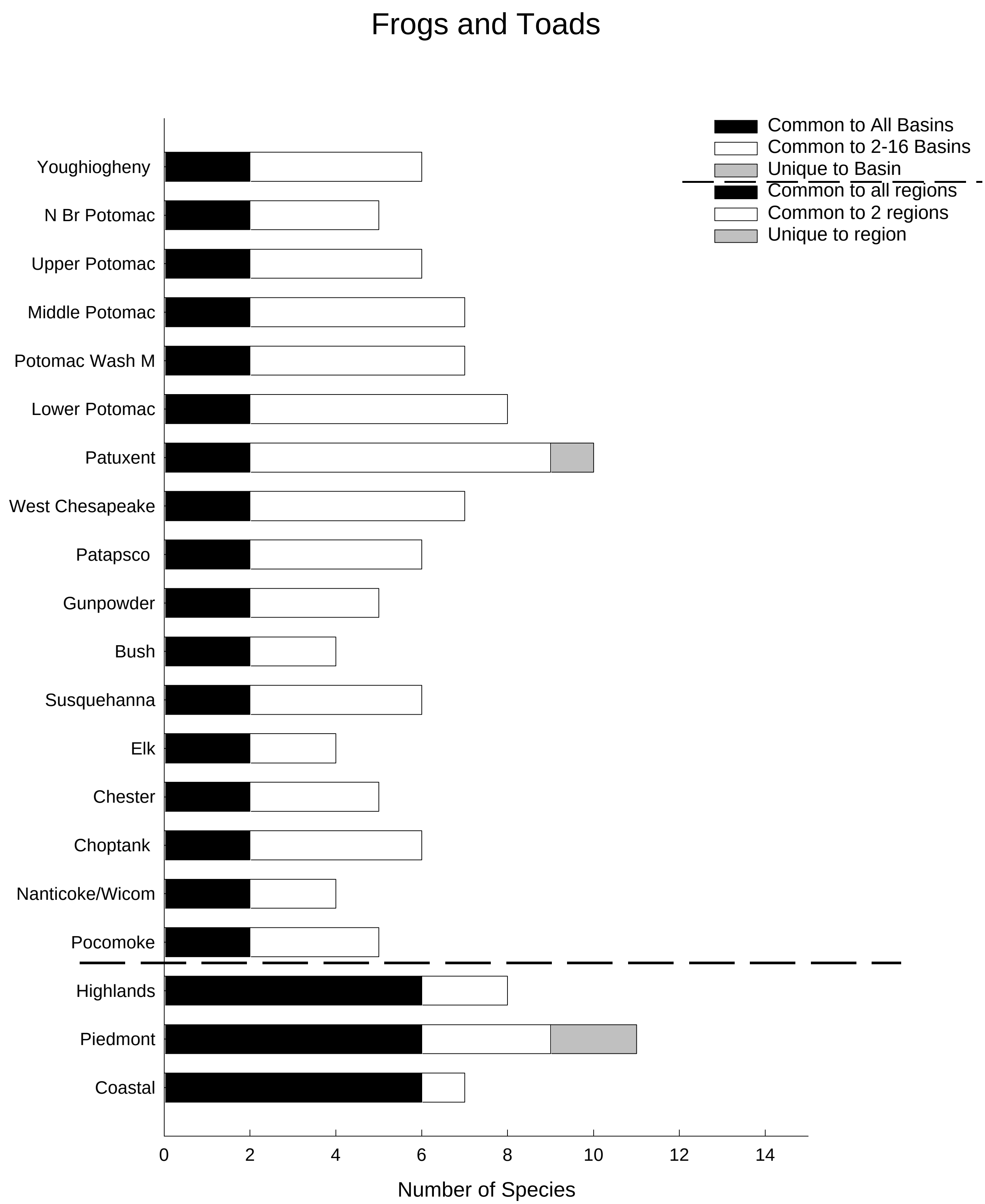

Figure 12-7. Frog and toad species richness by basin and geographic region for the 1995-1997 MBSS

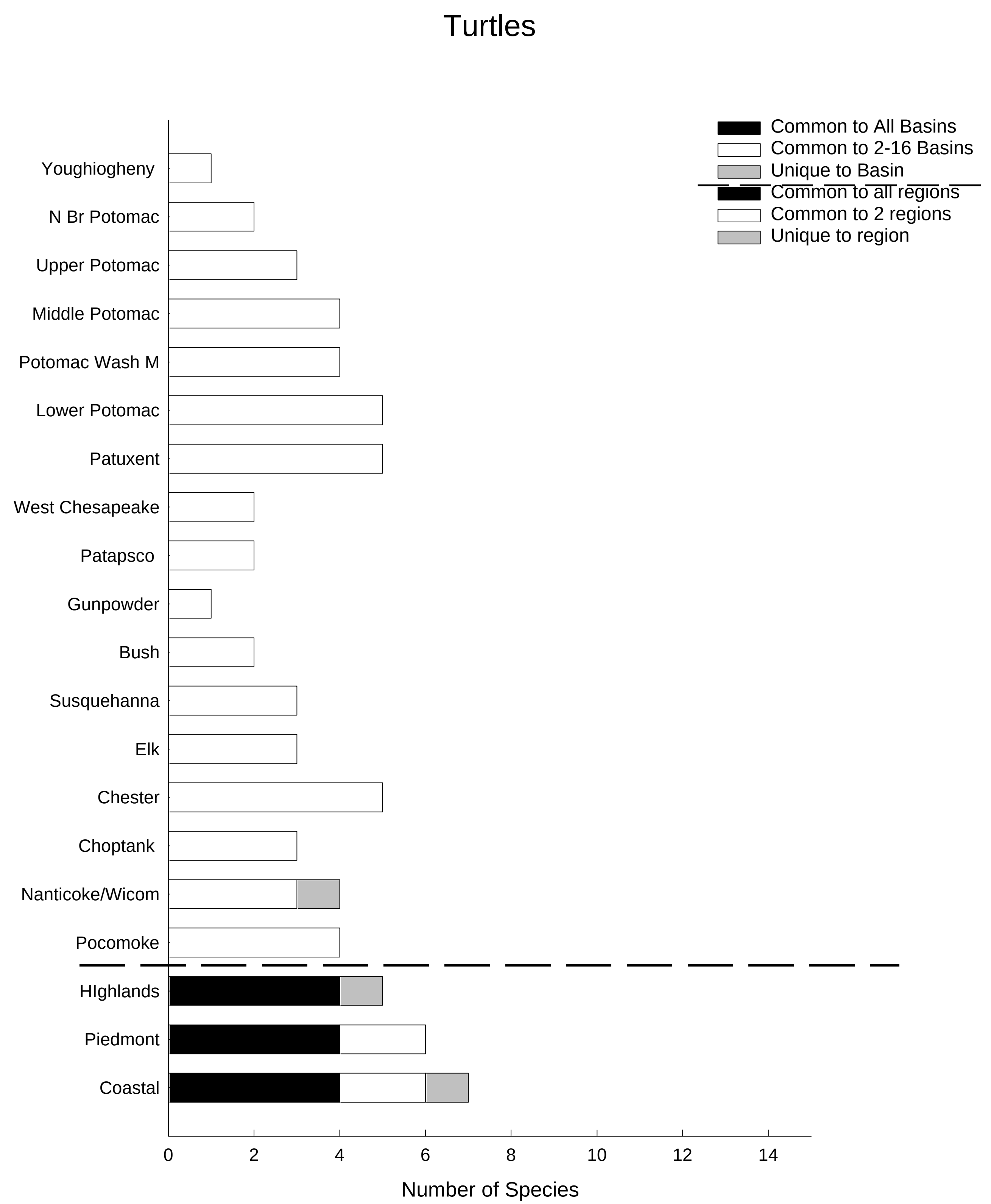

Figure 12-8. Turtle species richness by basin and geographic region for the 1995-1997 MBSS

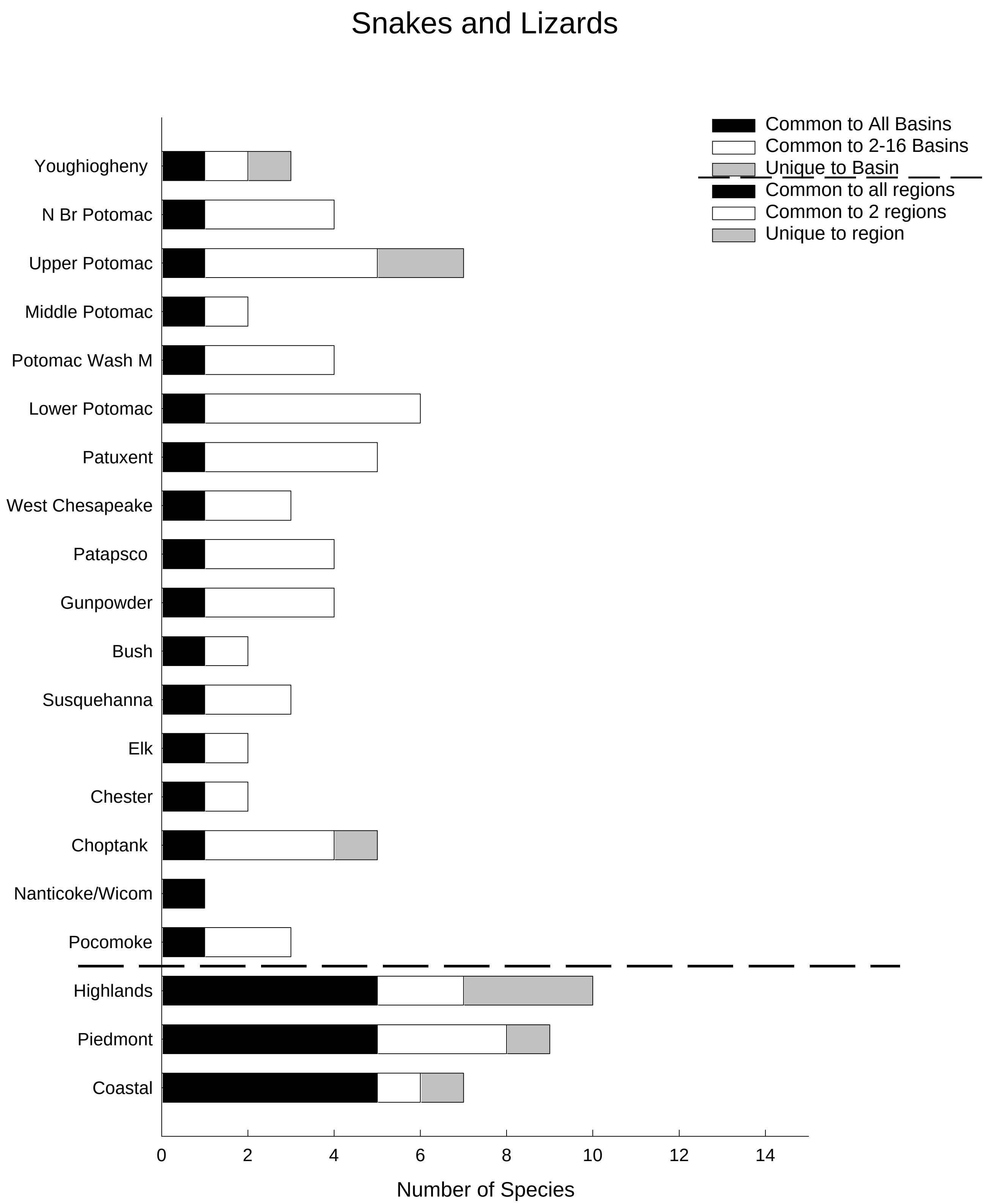

Figure 12-9. Snake and lizard species richness by basin and geographic region for the 1995-1997 MBSS

Table 12-1. Freshwater unionid mussel species listed as rare, threatened, or endangered in Maryland (MDNR 1997)

Common Name	Scientific Name	Status
Dwarf wedge mussel	*Alasmidonta heterodon*	State and Federal Endangered
Triangle floater	*Alasmidonta undulata*	State Endangered
Brook floater	*Alasmidonta varicosa*	State Endangered
Alewife floater	*Anodonta implicata*	Rare
Northern lance	*Elliptio fisheriana*	Rare
Yellow lance	*Elliptio lanceolata*	Rare
Atlantic spike	*Elliptio producta*	Rare
Yellow lampmussel	*Lampsilis cariosa*	State Endangered Extirpated
Eastern lampmussel	*Lampsilis radiata*	Rare
Green floater	*Lasmigona subviridis*	State Endangered
Tidewater mucket	*Leptodea ochracea*	Rare
Eastern pondmussel	*Ligumia nasuta*	Rare
Squawfoot	*Strophitus undulatus*	Rare
Paper pondshell	*Utterbackia imbecillis*	Rare

There is still considerable controversy over the nomenclature of various relatively small, elongated, freshwater mussels collectively referred to as the lanceolate *Elliptio* complex (Johnson 1970). This complex comprises what may or may not be several distinct species. Generally, only electrophoresis (a process by which proteins can be separated) or DNA testing can be used to accurately separate one species from another. Based upon electrophoretic studies, Davis et al. (1981) suggest that the number of species of lanceolate elliptios has been greatly underestimated. As a result, there is ongoing controversy about whether the species of lanceolate *Elliptio* that are found in Maryland are actually the Atlantic spike (*E. producta*), northern lance (*E. fisheriana*), Carolina lance (*E. angustata*), yellow lance (*E. lanceolata*), or still another species. In Maryland, it has been commonly assumed that the most common lanceolate *Elliptio* species are the northern lance on the eastern shore, and the Atlantic spike on the western shore.

Statewide, seven species of freshwater unionid mussels were observed during MBSS sampling in 1995 to 1997, including four species listed as rare or endangered in Maryland: alewife floater, northern lance, squawfoot, and yellow lance. Overall, freshwater unionid mussels were found at 9.9% (90) of the sites sampled. Unionid mussels were collected in only 1.7% of the first-order sites, 9.5% of the second-order sites, and 19% of the third-order sites.

Only five basins contained more than two mussel species and the North Branch Potomac contained none (Figure 12-10). The Chester contained the most species with six, including one (yellow lance) found only in that basin. The only other mussel species unique to a single basin was the squawfoot in the Middle Potomac.

When the distribution of native mussel species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, three occurred in all three regions, while one was unique to the Highlands and two were unique to the Coastal Plain (Figure 12-10).

12.1.5 Aquatic Vegetation

During the MBSS sampling in 1995 to 1997, 12 species of submerged aquatic vegetation (SAV), 10 species of emergent vegetation, and 2 species of floating vegetation were observed. The number of species of aquatic vegetation ranged from zero in the North Branch Potomac to 12 in the Choptank (Figure 12-11). Only the Choptank basin contained more than 10 aquatic plant species; three basins contained seven to 10 species. Five basins (Middle Potomac, Potomac Washington Metro, Lower Potomac, Bush, and Choptank) each contained one species unique to that basin.

When the distribution of aquatic vegetation species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, 9 occurred in all three regions, while 2 to 4 were unique to any one region (Figure 12-11).

12.2 RARE SPECIES

The Survey can provide information on the occurrence and abundance of State rare, threatened, or endangered species.

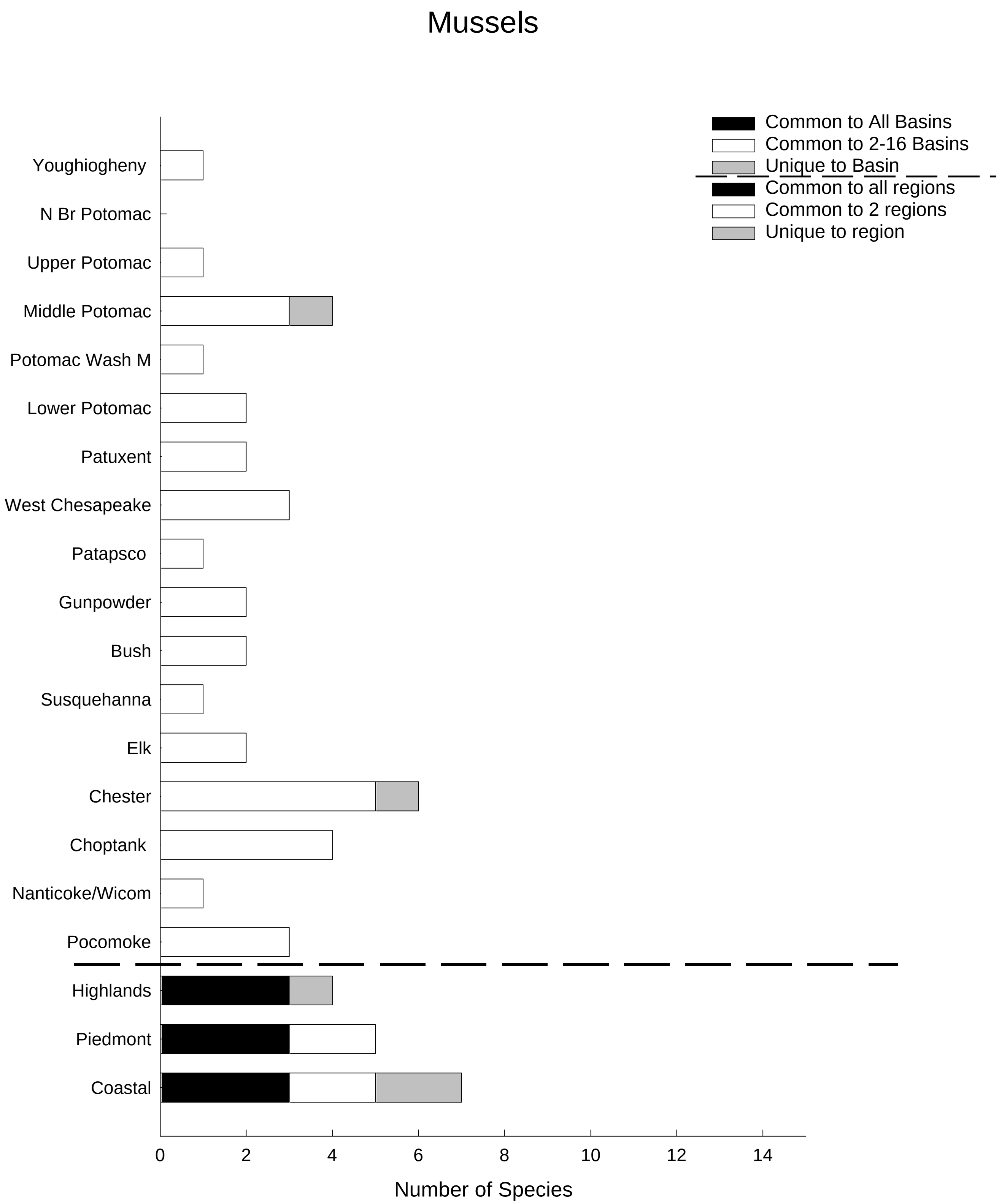

Figure 12-10. Mussel species richness by basin and geographic region for the 1995-1997 MBSS

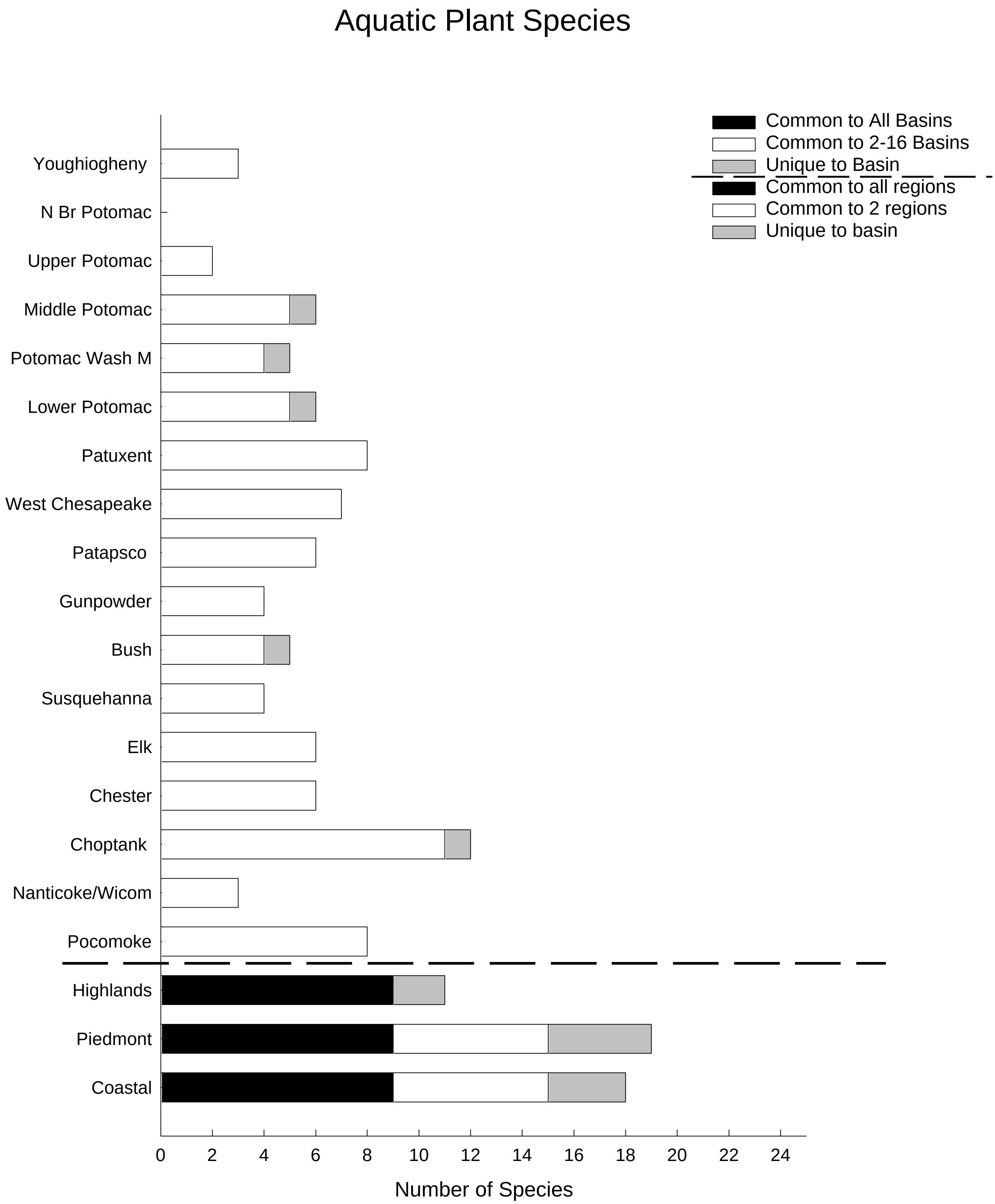

Figure 12-11. Aquatic plant species richness by basin and geographic region for the 1995-1997 MBSS

A state list of rare species is maintained by Maryland DNR's Heritage and Wildlife Division based on evidence from numerous sources, including historical data and more recent field investigations (MDNR 1997). Each species is assigned a state rank; some species also have a state status as endangered or threatened that carries legal protection. Six fish, one amphibian, and five mussel species listed by the Maryland DNR (1997) Natural Heritage Program were captured by the Survey in 1995 to 1997:

- Stripeback darter (*Percina notogramma*) - Highly state rare, state endangered extirpated
- Glassy darter (*Etheostoma vitreum)* - Highly state rare, state endangered
- Ironcolor shiner (*Notropis chalybaeus*) - Highly state rare
- Logperch (*Percina caprodes*) - Highly state rare
- Mud sunfish (*Acantharchus pomotis*) - State rare
- Flier (*Centrarchus macropterus*) - State status uncertain, but possibly rare

- Jefferson salamander (*Ambystoma jeffersonianum*) - State watch list
- Alewife floater (*Anodonta implicata*) - State rare
- Atlantic spike (*Elliptio producta*) - State rare
- Northern lance (*Elliptio fisheriana*) - State rare
- Squawfoot (*Strophitus undulatus*) - State rare
- Yellow lance (*Elliptio lanceolata*) - State rare

No federally-listed threatened or endangered species were found by the survey.

Although state-listed rare and endangered fish are found in several sub-basins throughout Maryland, some areas, like Zekiah Swamp in the Lower Potomac basin, Tuckahoe Creek in the Choptank basin, and the Upper Pocomoke River, have up to four such species in their watersheds (Figure 12-12). Watersheds of the Casselman River in the Youghiogheny basin, Lower Monocacy River in the Middle Potomac basin, Western Branch of the Patuxent River, and the Pocomoke River each contain up to three rare, threatened or endangered fish species.

Because the core Survey uses a probability-based sampling design, we were able to develop an independent list of rare fish species. For the purposes of this analysis, we defined

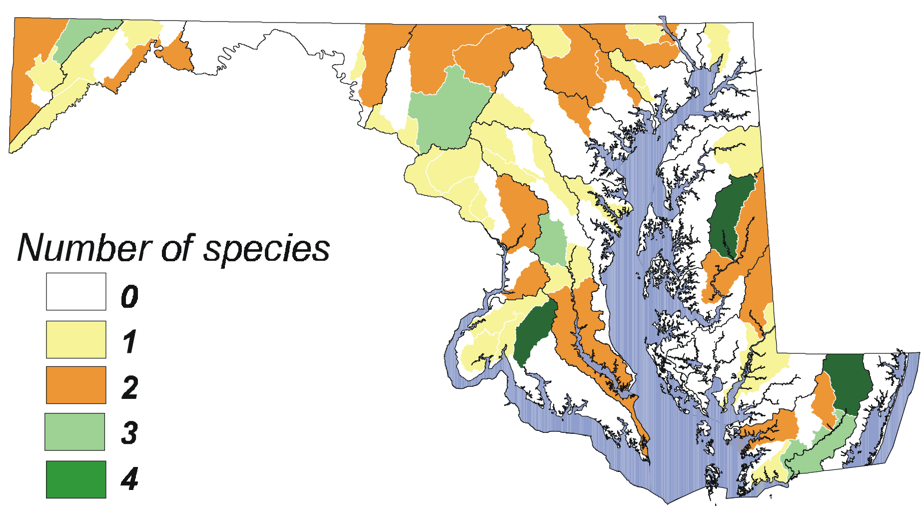

Figure 12-12. Distribution of state-listed rare and endangered fish found in the 1995 - 1997 MBSS, by watershed

as rare those fish species occurring at approximately 2% or fewer of the 905 randomly selected MBSS sites sampled in 1995 to 1997 (species known to be more abundant in large streams or tidal waters not sampled by the Survey were excluded from the list). Table 12-2 presents the first statistically reliable estimates of fish species rarity (percentage of stream sites where present) in Maryland. Designation as rare was corroborated by the population abundance estimates for these species, 11 of which were below 25,000 individuals statewide.

All of the Heritage-listed species captured by the Survey met our 2% sampling-based definition of rarity, confirming the status of these species as geographically rare. Those species found at less than 2% of MBSS sites are overlain on a map of watershed fish species richness in Figure 12-13. Clusters of sites with one to four rare fish species occur in five areas of the State.

12.3 VULNERABLE FISH POPULATIONS

Although the size of fish populations that can effectively sustain themselves over time may vary widely and is not generally known, low population size usually indicates increased risk of extirpation in a basin (for this analysis, 500 individuals was chosen as a threshold representing the low end of estimates calculated for all fish species collected). The Survey has the ability to provide precise estimates of non-tidal stream fish populations in each sampled basin. Using 1995-1997 MBSS data, a fish population was characterized as being at greater risk of extirpation if (1) the estimated population size in a basin was 500 individuals or less and (2) the distribution of the species was expected or known to be primarily restricted to first through third order non-tidal streams. For example, *Fundulus* sp. (killifish) non-tidal populations of less than 500 were not considered at risk because the group occurs extensively in tidal streams

Table 12-2. Rare fish species occurring at approximately 2% or fewer MBSS sites

Species	Percentage of Sites	Total Abundance+
Rainbow darter	0.11	124
Logperch*	0.22	8,185
Stripeback darter*	1	580
Flier*	0.44	1335
Glassy darter*	0.55	4825
Ironcolor shiner*	0.66	2919
Comely shiner	0.77	3,639
Striped shiner	0.77	10,152
American brook lamprey	1.2	178,009
Checkered sculpin	1.2	475,984
Mud sunfish*	1.3	3,519
Warmouth	1.3	24,005
Pearl dace	1.4	497,025
Johnny darter	1.6	77,012
Swamp darter	2.2	9,286

***On Maryland State Heritage List**
+Statewide estimate adjusted for capture efficiency

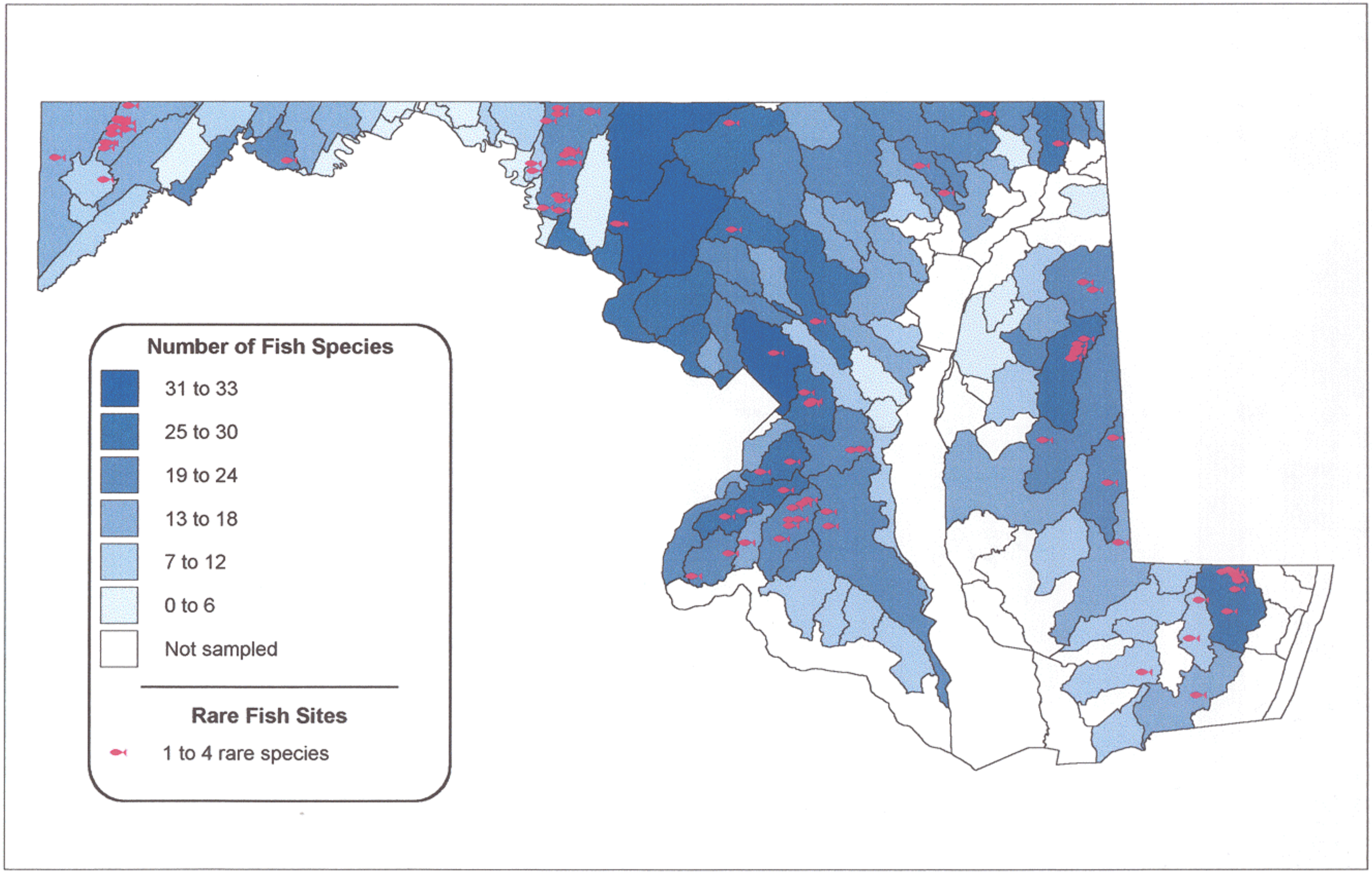

Figure 12-13. Overlay of watershed fish species richness and sites with rare fish species

Figure 12-13. Overlay of watershed fish species richness and sites with rare fish species

and embayments. Non-native fish were also not considered in this analysis.

Of the 17 basins in Maryland, only the Nanticoke/Wicomico did not contain a fish population with less than 500 individuals (based on adjusted population estimates). One to four species with populations less than 500 were found in the other 16 basins (Table 12-3). Of those populations potentially at greater risk of extirpation, ten populations met the MBSS criteria of being rare based on occurrence at less than 2% of sample sites (see section 12.2): striped shiner (Youghiogheny 1997), rainbow darter (North Branch Potomac), American brook lamprey (Potomac Washington Metro), swamp darter (Lower Potomac, Chester, Choptank 1996), logperch (Elk), ironcolor shiner (Choptank 1996), mud sunfish (Choptank 1996), and glassy darter (Pocomoke). The remaining 30 populations with less than 500 individuals represent more widespread species that are either at the edge of their range or are suffering declines from anthropogenic influences.

For example, populations of redfin pickerel (*Esox americanus*) and creek chubsucker (*Erimyzon oblongus*), two species common to Maryland's Coastal Plain, may be at risk in the Patapsco basin because there is little Coastal Plain habitat. In addition, what little Coastal Plain and wetland habitat occurs in this basin appears to be suffering losses from anthropogenic activities. Similarly, the eastern mudminnow, an extremely abundant Coastal Plain species, is vulnerable in the Bush basin, where it is on the edge of its natural range. In another example, the sea lamprey, a species abundant in much of North America, appears to be uncommon throughout Maryland. This is likely the result of numerous migration barriers and the susceptibility of larval lampreys to periodic water quality problems.

12.4 FISH HYBRIDS

Hybridization sometimes occurs when species are brought together through range expansions or habitat homogenization (usually as a result of environmental degradation). Hybridization can also result from introductions of non-native species such as some members of the genus *Lepomis*. A total of 63 hybrids (47 *Lepomis*, 16 cyprinids) were collected by the Survey in 1995 to 1997. Nearly 80% of the *Lepomis* hybrids were observed in the Upper Potomac (23) and Middle Potomac (14) basins. All but one of the cyprinid hybrids were observed in the Bush basin. Hybrids represented the highest percentage in the Middle Potomac basin at 1%; the percentage of hybrids was at least an order of magnitude less in all other basins.

12.5 NON-NATIVE SPECIES

There has been considerable debate over the virtues and threats of introduced species, especially those "naturalized" species (e.g., valued game fish species) that have been part of Maryland stream communities for decades. The conservation of biodiversity does not address recreational fisheries benefits, but rather focuses on maintaining native species as representatives of co-evolved natural systems. Although introduced gamefish species may benefit recreational fishermen, they may adversely affect the native fish community and thus degrade biodiversity. The invasion of non-native molluscs also has the potential to degrade the imperiled native mussel fauna and otherwise adversely affect natural ecosystems. The Chesapeake Bay Program recognizes this potential for deleterious effects in its policy guidelines on the introduction of non-native aquatic species into the Chesapeake Bay drainage (Chesapeake Bay Program 1993).

One of the most dramatic examples of expansion by a non-native aquatic species in Maryland is the Asiatic clam, *Corbicula fluminea* (Phelps 1994). First introduced into the Potomac River in the mid-1970s, the Asiatic clam has expanded its range into 13 of the 17 river basins in Maryland according to the results of the 1995-1997 MBSS. Although it occurred in most basins, the Asiatic clam found in relatively few sites in each basin (Figure 12-14). Statewide, the Asiatic clams was found at 7.7% (70) of the sites sampled, ranging from 0.7% of first-order streams to 5.1% of second-order to 18% of third-order. The troublesome non-native zebra mussel, *Dreissena polymorpha*, was not found during 1995-1997 MBSS sampling, but it should be noted that the habitat requirements of the zebra mussel are very similar to those of the Asiatic clam (Claudi and Mackie 1994).

How pervasive non-native fish species are in each basin is an important indicator of loss of biodiversity. Where non-native species make up a large proportion of the number of species or individuals in a basin, the natural ecological or evolutionary processes of the fish communities have likely been substantially altered. An analysis of the relative proportion of non-native fish per stream mile in each basin reveals substantial differences among basins with generally higher occurrences farther east (Figure 12-15). The density (and relative proportion) of non-native fish was greatest in the Nanticoke/Wicomico basin (1,225 non-native fish per mile, 24% of the total number of fish per mile) and lowest in the North Branch Potomac basin (32 non-native fish per mile, 1.2% of the total).

Table 12-3. Vulnerable fish species by basin (population less than 500) for the 1995-1997 MBSS, non-tidal, small streams only

	Adjusted Abundance	**Standard Error**
Youghiogheny 1997		
Green sunfish	110	114
Smallmouth bass	264	243
Striped shiner	330	330
Bluegill	440	451
North Branch Potomac		
Creek chubsucker	144	133
Rainbow darter	144	144
Pumpkinseed	212	133
Upper Potomac		
River chub	61	61
Northern hogsucker	490	368
Middle Potomac		
Swallowtail shiner	272	242
Creek chubsucker	471	284
Potomac Washington Metro		
Bluespotted sunfish	65	53
Redfin pickerel	194	194
American brook lamprey	362	270
Lower Potomac		
Swamp darter	138	94
Common shiner	268	281
Patuxent		
Chain pickerel	121	141
Bluntnose minnow	134	112
West Chesapeake		
Swallowtail shiner	19	19
Redbreast sunfish	19	21
Satinfin shiner	154	123

Table 12-3. Cont'd		
	Adjusted Abundance	**Standard Error**
Patapsco 1995		
Creek chubsucker	125	129
Bluespotted sunfish	258	258
Chain pickerel	322	275
Patapsco 1996		
Redfin pickerel	345	345
Creek chubsucker	460	507
Gunpowder		
Fallfish	123	113
Bush		
Sea lamprey	287	264
Eastern mudminnow	469	457
Susquehanna		
Golden shiner	172	100
Elk		
Least brook lamprey	61	53
Logperch	182	182
Chester		
Sea lamprey	71	40
Rosyside dace	115	102
Swamp darter	472	340
Choptank 1996		
Swamp darter	115	92
Ironcolor shiner	138	84
Mud sunfish	138	85
Pocomoke		
Glassy darter	49	33
Chain pickerel	110	86

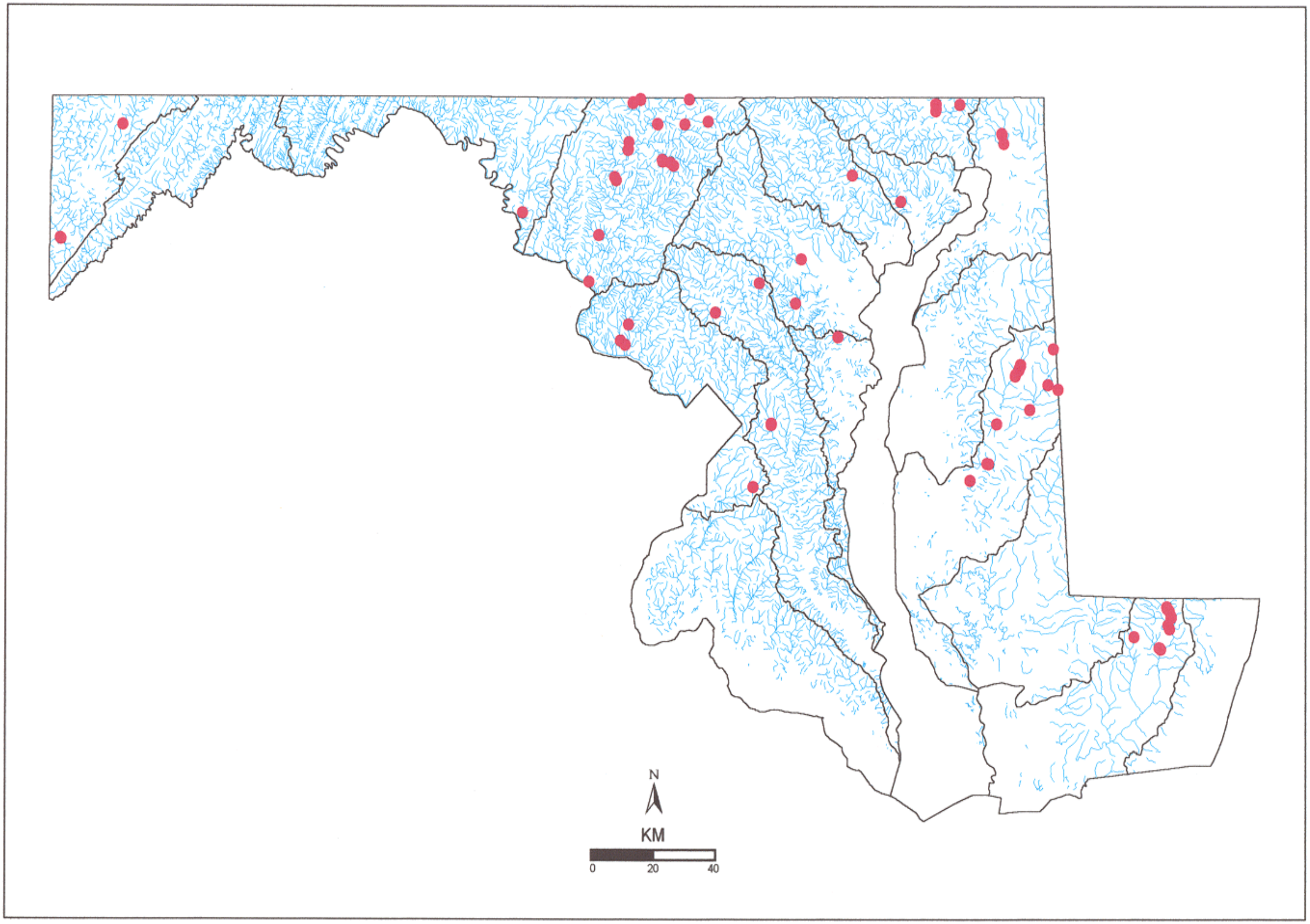

Figure 12-14. Presence of Asiatic clam (*Corbicula fluminea*) at 1995-1997 MBSS sampling sites

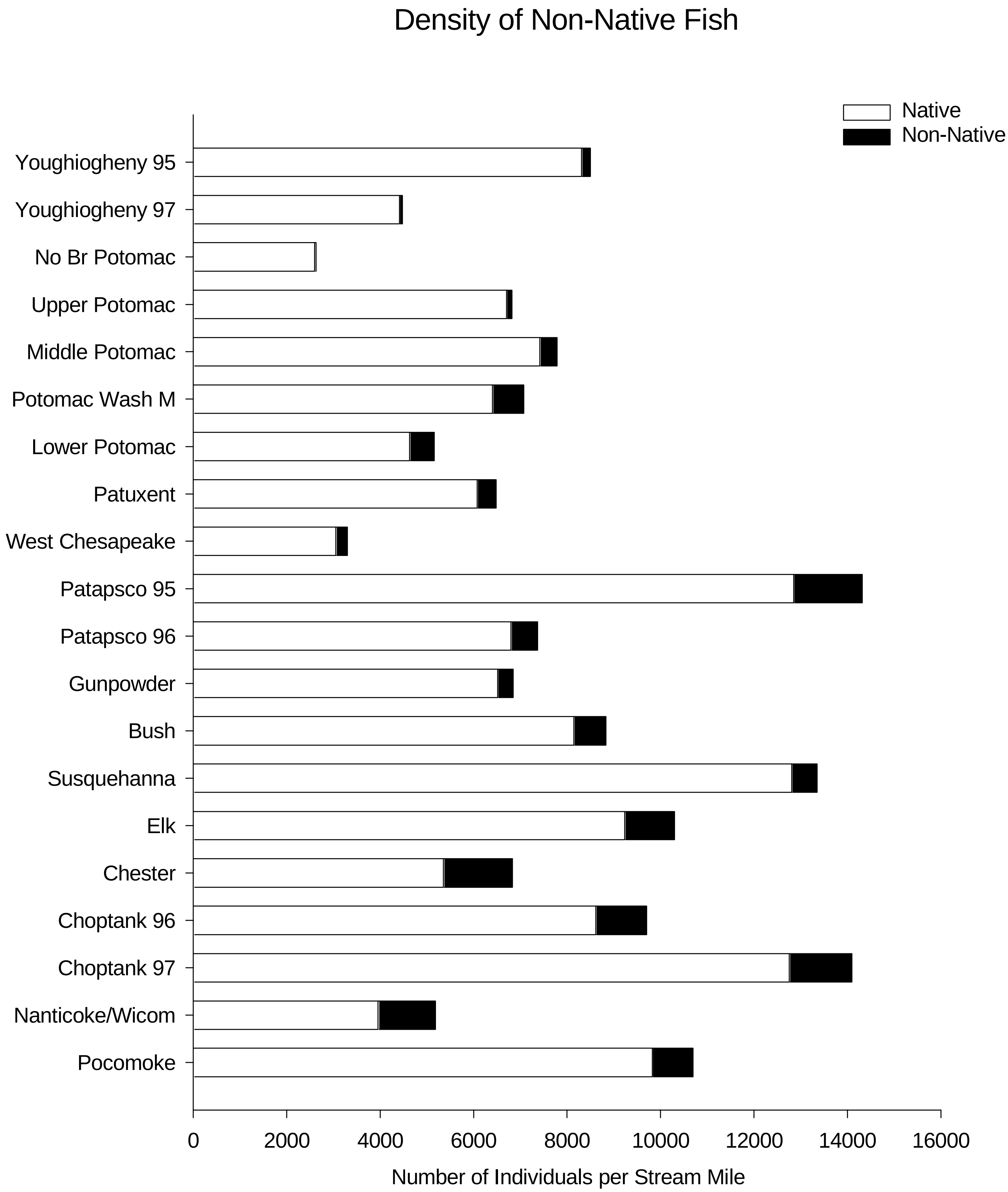

Figure 12-15. Density of native and non-native fish species for basins sampled in the 1995-1997 MBSS. Density estimates are adjusted for capture efficiency.

Although non-native fishes made up a fairly small percentage of the total fish fauna, these non-native species were widespread geographically. Statewide, 46% of first-to third-order streams contained non-native fish species. Thirteen of the 17 river basins contained non-native fish species in more than 50% of first- to third-order stream miles (Figure 12-16). The highest percentage of stream miles with non-native fish was in the eastern part of the State with basins in the Eastern Shore all exceeding 50%. In contrast, more western basins had the lowest percentages of stream miles with non-native fish: Youghiogheny 1995 (10%), Youghiogheny 1997 (30%), North Branch Potomac (17%), Upper Potomac (25%), and West Chesapeake (13%). Larger streams are more likely to have non-native fish than small streams (Figure 12-17). An estimated 86% of third-order and 68% of second-order streams had non-native fish species. In contrast, 46% of first-order stream had non-native fish.

Across all basins, a total of 19 non-native fish species were captured (Table 12-4). Note that different subsets of species are considered native to the Youghiogheny drainage versus the Chesapeake drainage. Although the Chester and Choptank basins contain some of the highest densities of non-native fish, these numbers result from the fewest number of species; only black crappie, bluegill, and largemouth bass were found. In contrast, six Maryland basins contained 10 or more non-native fish species: Upper Potomac (14), Middle Potomac (11), Potomac Washington Metro (10), Patuxent (9), Patapsco (12), and Susquehanna (10). Among the 19 non-native fish species in Maryland, seven are gamefish, and they included the ubiquitous (occurring in all 17 basins) bluegill, largemouth bass, and pumpkinseed.

12.6 NATURAL STREAM ECOSYSTEMS

The description of the distribution and abundance of aquatic ecosystems is more difficult than the characterization of species diversity, because we lack an effective classification of aquatic ecosystem types. Within the non-tidal stream ecosystem type itself, there is considerable natural variation in the composition of aquatic communities among stream orders and geographic areas. Other factors, such as local climate, soils, and historical events, also affect ecosystem diversity. This suite of factors also determines landscape diversity (the distribution and abundances of landscapes within a larger region) by influencing the dendritic network of streams in a river basin. Given these relationships, a rigorous assessment of aquatic diversity requires both a classification of ecosystem and landscape types and an analysis of their geographic pattern.

Recognizing that the Survey does not currently provide the information for such a rigorous analysis, several kinds of results can be used to identify streams and stream networks that are noteworthy examples of naturally functioning community or ecosystem types. In developing the provisional Index of Biotic of Integrity for fish (Roth et al. 1999), cluster analyses of the fish species compositions at each sample site identified major differences between the Highlands, Eastern Piedmont, and Coastal Plain regions of Maryland. Additional cluster analyses with additional MBSS data may reveal other regions or stream types that contain different characteristic communities of fish or other organisms. It is also possible that the common evolutionary and ecological history of stream ecosystems within a single river basin constitutes a unique ecosystem type. For the purposes of this report, MBSS data were used to identify (1) least disturbed or high-integrity streams (i.e., those rated as good for the fish IBI or benthic IBI) and (2) streams with only native fish species. These areas of high biological integrity and original species composition are, by definition, areas that function most naturally and contribute to biodiversity at the ecosystem and landscape levels.

12.6.1 High-Integrity Streams

The fish and benthic IBIs developed by the Survey are indicators of the degree to which human activities have altered natural conditions in streams based on deviation from minimally impaired reference sites. We recognize that these reference sites inevitably have some degree of anthropogenic influence (e.g., atmospheric deposition), but they serve as a useful means of designating an IBI score to denote "natural" communities likely to support original ecological and evolutionary processes. For the purposes of this analysis, natural streams are those that received a “good” IBI rating of at least 4.0 on a 1 to 5 point scale (see Chapter 5).

Of the 17 basins in Maryland, the Elk, Bush, and Lower Potomac were the only basins with more than one-third of stream miles in good condition based on the fish IBI (see Table 5-4 in Chapter 5). In contrast, less than 10% of the stream miles in the Nanticoke/Wicomico, Upper Potomac, and West Chesapeake were classified as good. The number of high integrity stream miles based on the fish IBI generally corresponded well with the physical habitat index, but did not correlate with the benthic IBI. Statewide, 20% of stream miles were rated good by the fish IBI, 11% were rated good by the benthic IBI, and 33% were rated good by the Physical Habitat Index. Only 21 sites sampled by the Survey were rated as good for all three indicators; 38 sites were rated as good by both the fish IBI and benthic IBI.

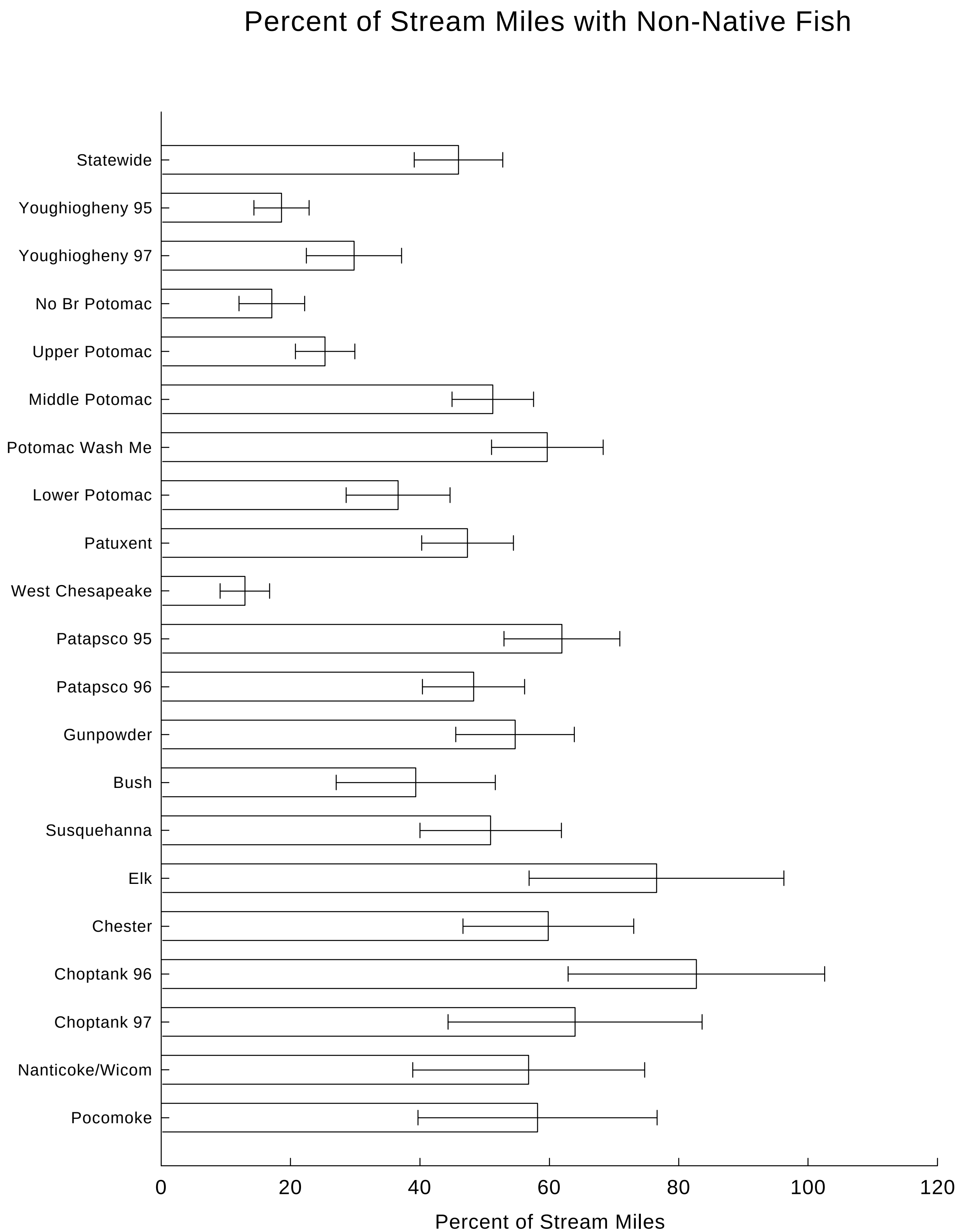

Figure 12-16. Density of non-native fish species for basins sampled in the 1996-1997 MBSS. Error bars represent ± 1 standard error

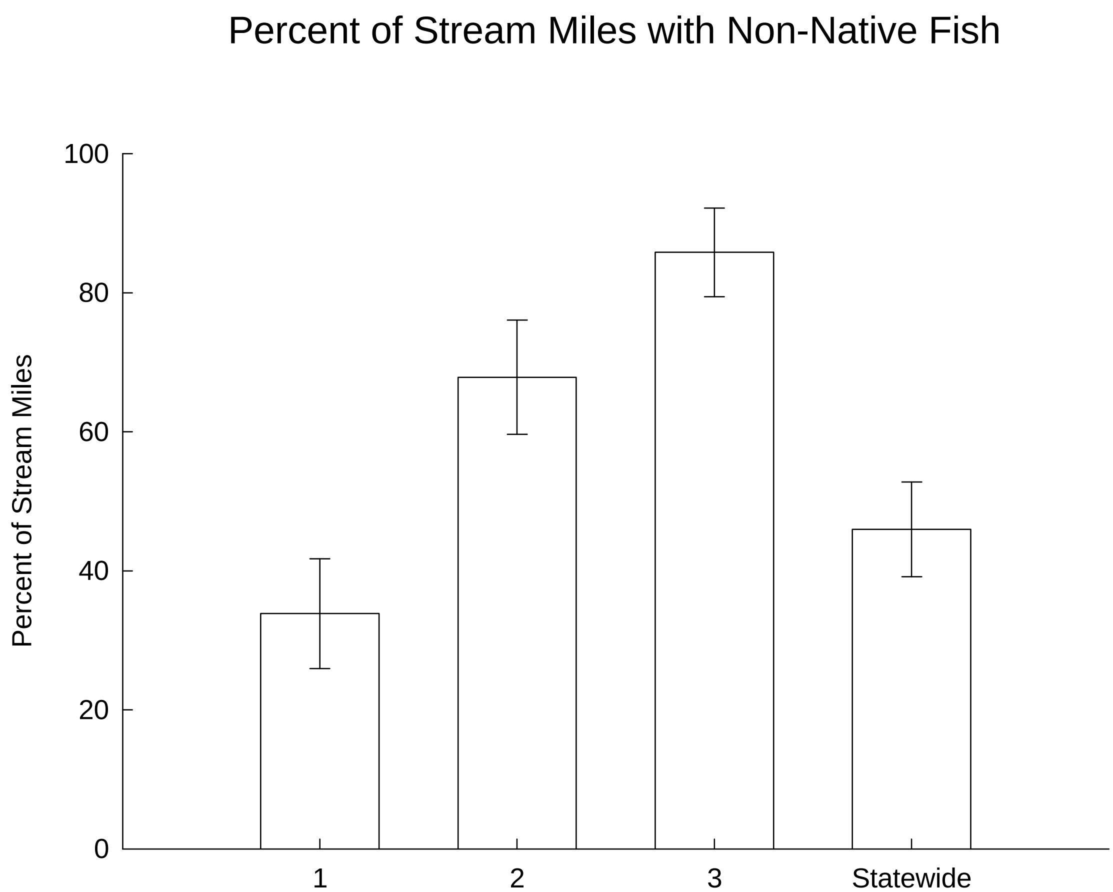

Figure 12-17. Percentage of stream miles with non-native fish species, by stream order, 1995-1997 MBSS. Error bars represent ± 1 standard error.

The 38 sites with high biological integrity were distributed among 10 river basins with nine in the Youghiogheny and eight in the Lower Potomac basins (Figure12-18). These sites likely represent some of the most natural stream ecosystem conditions in Maryland.

This approach to identifying natural stream ecosystems can be expanded to the landscape level by looking on a finer scale at those stream networks that have both multiple good sites and no poor sites (using the fish IBI, benthic IBI, physical habitat index, or any combination of indices) as candidates for harboring unimpaired ecological and evolutionary processes. Such sites could be the focus of landscape-scale conservation efforts. At the same time, conservation efforts may be targeted on the few good streams that persist among many poor streams, the good streams may be the last remaining example at a vanishing ecosystem type.

12.6.2 Native-Only Streams

High-integrity streams are even more likely to support natural ecosystem processes in the absence of non-native species. Non-native species can dramatically alter species compositions and ecosystem processes (Hunter 1996). It is important to note that non-native species occur at many of the 264 good fish IBI sites. In 13 of the 17 basins sampled, at least 67% of the good stream sites (fish IBI of 4.0 or greater) contained one or more non-native species. Of those basins with more than 3 good stream sites, only the Upper Potomac (0% non-natives) and Susquehanna (7%) were generally free of non-natives.

Stream sites with only native fish species are fairly evenly distributed across the State (Southerland et al. 1998, 1999). However, only 56 of the 905 streams sampled in the 1995-1997 MBSS have only native fish species and high biological integrity (based on fish IBI scores). Twenty of these streams are clustered in the far western part of Maryland, while the others are scattered mostly in the central part of the State. Therefore, these streams provide another potential focus for biodiversity conservation efforts.

Table 12-4. Basins in which non-native fish species occur for the 1995-1997 MBSS																	
Fish Species	Youghiogheny	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank	Nanticoke/Wicomico	Pocomoke
Chain pickerel	Y		N		N	N	N	N	N				N	N	N	N	N
Redfin pickerel	Y				N	N	N	N	N		N		N	N	N	N	N
Common carp		I	I	I	I	I			I		I	I	I				
Fathead minnow	I		I	I	I	I	I		I	I							
Goldfish			I		I	I		I	I		I						
Channel catfish			C	C			C					C					C
Brown trout	I	I	I	I	I		I		I	I		I	I				
Cutthroat trout		I	I						I								
Rainbow trout	I	I	I	I	I		I	I	I	I	I	I	I				
Black crappie			C			C	C	C	C					C	C	C	C
Bluegill	N	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Green sunfish	N	C	C	C	C	C	C	C	C	C	C	C		C			
Largemouth bass	N	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Longear sunfish			C	C						C							
Pumpkinseed	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Rock bass	N	C	C	C	C				C	C		C					
Smallmouth bass	N	C	C	C	C		C		C	C	C	C	C				
Banded darter												I					
Yellow perch	Y	N			N	N	N	N				N	N	N	N	N	N

Notes:
I = Introduced in both the Youghiogheny and Chesapeake drainage basins
C = Introduced to the Chesapeake drainage basin only
Y = Introduced to the Youghiogheny drainage basin only
N = Occurs as a native to that basin

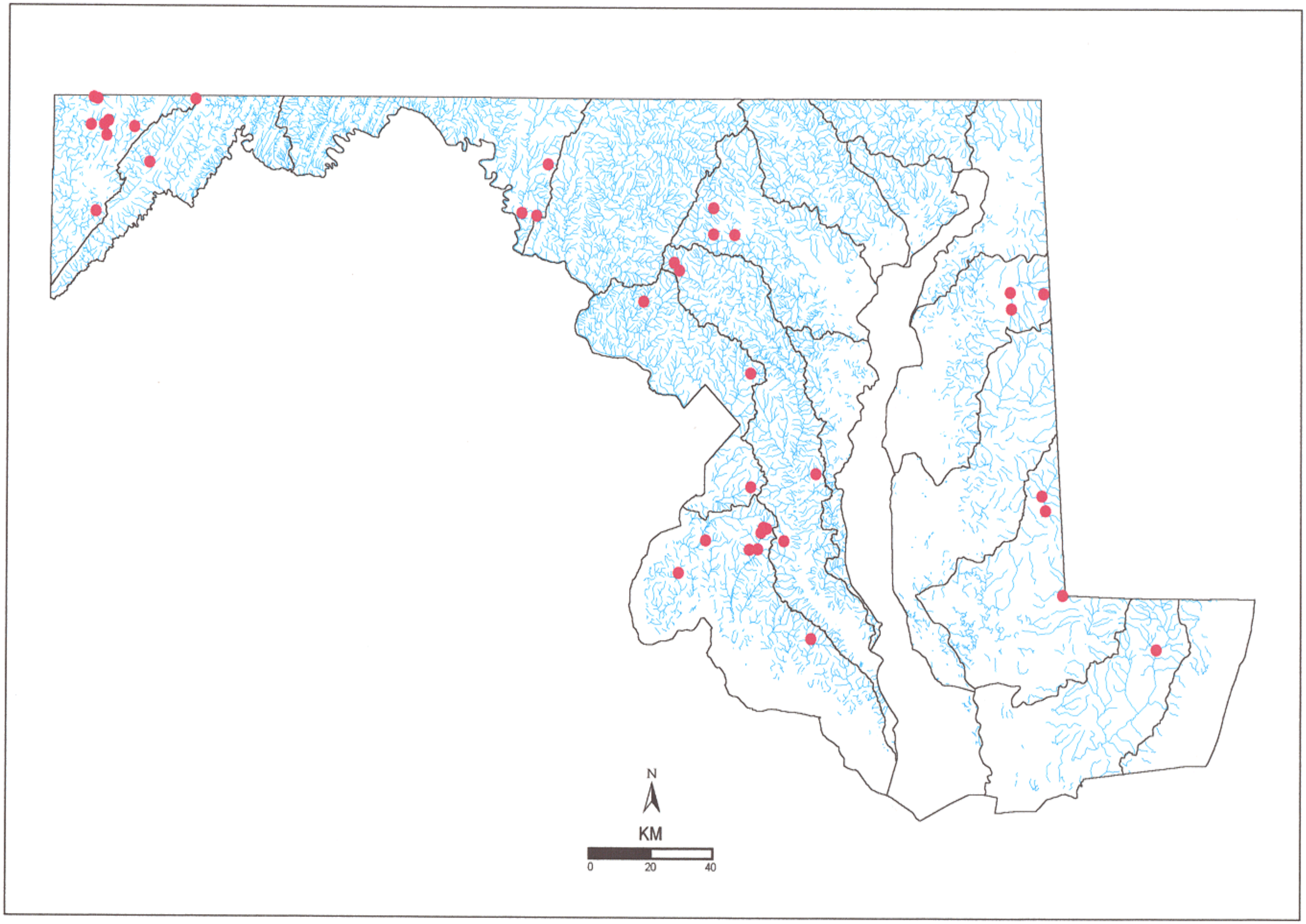

Figure 12-18. Sites that rated good (IBI scores ≥ 4.0) for both the fish and benthic Index of Biotic Integrity

13 IMPLICATIONS FOR MANAGEMENT AND POLICY

The goal of the Maryland Biological Stream Survey (MBSS or Survey) is to provide natural resource managers, policymakers, and the public with the information they need to make effective natural resource decisions. For this reason, the Survey was designed to answer a set of 64 management questions. These questions (see Appendix A) represented the direction and range of natural resource management concerns in 1995. The results described in this MBSS report provide scientifically defensible and management-relevant answers to the majority of these questions, in some cases the first such answers ever obtained. At the same time, certain management concerns have changed and programmatic needs have evolved. Some of the 64 questions are less important, while new questions need to be answered. The discussion in this chapter summarizes the answers to original MBSS questions and to other questions of concern. The next section describes the relevance of these answers to current natural resource management and policy initiatives. Finally, questions that remain to be answered and their implications for future implementation of the Survey are discussed in Chapter 14-Future Directions of the MBSS.

13.1 ANSWERS TO MBSS MANAGEMENT QUESTIONS

At the early stages of the Survey, environmental and natural resource managers developed a list of management questions that potentially could be answered with MBSS data. The Survey was designed specifically to answer many of these questions at a statewide and basinwide level and thus to provide a greater understanding of the condition of Maryland's non-tidal streams and the stressors affecting stream resources. Over the course of the 1995-1997 MBSS, we addressed many of these questions through careful analysis of the data. Detailed answers are incorporated throughout this report. Here, we summarize answers to MBSS questions, which fall under the general topics of physical characteristics, water chemistry, biological resources, landscape characteristics, resource-stressor associations, and resource-landscape associations. Because management concerns and priorities evolve, we have also addressed several new questions of interest to DNR, that have been identified over the course of the Survey.

For brevity, questions are answered below with a short summary of statewide results. Additional information may be found in the referenced sections of this report. Basin-specific answers to many of the questions are also found in the sections noted. In addition, basic water chemistry, physical habitat, and fish population estimates have been reported in individual basin data summaries for each sample year: 1995 (Roth et al. 1997, Appendix F), 1996 (Roth et al. 1998, Appendix D) and 1997 (Roth et al. 1999).

13.1.1 Physical Characteristics

How many wadeable stream miles of each stream order are in the study area?

- According to the 1:250,000 base map used by the Survey, there are 5,820 miles of first- order, 1,499 miles of second-order, and 692 miles of third-order streams, for a total of 8,010 miles of first- through third-order streams in the study area (Appendix B). This represents the vast majority of stream miles in Maryland.

What is the geographic distribution of these streams?

- The greatest number of first- through third-order stream miles were in the Middle Potomac basin. The breakdown of stream miles by order for all 17 basins sampled in the Survey is shown in Appendix B.

How many stream miles in the study area are remote?

- An estimated 17% of stream miles were difficult to access (i.e., received the highest remoteness rating) and another 26% were moderately difficult to access (Section 7.2.5 and Appendix D).

What % of streams in the study area are estimated to be ephemeral (i.e., dry at the time of summer sampling)?

- Less than 5% of stream miles were ephemeral. The percentage varied slightly by year. In 1996, a wet year, an estimated 2.8% of stream miles in sampled basins were ephemeral, compared with 5.3% in 1995 and 4.2% in 1997 (Section 10.1).

What % of stream miles are obstructed by beaver dams or other barriers?

- An estimated 4% of stream miles had evidence of beaver activity. Artificial blockages were observed at 18 sites out of the 905 sampled during summer (Section 7.2.2 and Appendix D).

What % of stream miles are channelized with bank revetment or artificial banks?

- Statewide, an estimated 17% of stream miles were channelized. Individual basins had up to 81% of stream miles channelized (Section 7.2.2).

What % of stream miles have low bank stability?

- An estimated 13% of stream miles received ratings of poor for bank stability, while another 34% were rated as marginally stable (Appendix D).

  Assessments of bank erosion potential showed similar results. Statewide, 7% of stream miles had highest potential for bank erosion, while another 35% had high potential, according to an erodibility index that combines several aspects of bank condition (Section 7.2.3).

What % of stream miles have selected types of riparian buffers?

- Fifty-eight percent of stream miles had forested buffers, 14% had other kinds of vegetated buffers (wetland, old field, tall grass, or lawn), and 28% had no effective vegetation in the riparian zone. (Section 7.2.1 and Appendix D).

What % of stream miles have selected widths of riparian buffers?

- Statewide, 40% of stream miles had at least a 50-m riparian buffer, 13% had a 19-49 m buffer, 12% had a 6-18 m buffer, 7% had a 1-5 m buffer, and 28% had no effective buffer. Riparian buffer widths varied by basin (Section 7.2.1 and Appendix D).

What % of stream miles have little shading?

- Statewide, 8% of stream miles had very little shading (0-25% coverage), and 10% had little shading (25-50% coverage) (Appendix D).

What % of stream miles have high aesthetic quality?

- An estimated 43% of stream miles had high aesthetic quality (Section 7.2.5 and Appendix D).

What % of stream miles have low instream habitat quality (e.g., high embeddedness)?

- A number of parameters were used to evaluate different aspects of instream habitat quality (Section 7.2.5 and Appendix D). Twelve percent of stream miles had poor instream habitat structure and 31% had poor epifaunal substrate. Velocity/depth diversity was rated poor in 12% of stream miles, while 10% rated poor for pool/glide/eddy quality. Riffle/run quality was poor in 16% of stream miles and 28% of stream miles had a high percentage of embeddedness.

What % of stream miles in the study area are estimated to be publicly vs. privately owned?

- Statewide, an estimated 79% of stream miles were on private land, while only 17% were public. Within some individual basins, the extent of private ownership was even higher (Section 13.2.5).

What is the geographic distribution of streams with these physical characteristics across the state?

- Geographic variation was noted for many of the physical habitat characteristics recorded by the Survey. Comparisons among basins are presented for several individual parameters (Section 7.2).

What % of stream miles have habitat conditions that differ from reference conditions as measured by indicators of stability (e.g., bank erosion) and diversity (e.g., substrate types)?

- The Physical Habitat Index (PHI), which combines multiple aspects of physical habitat condition, rated 29% of stream miles as poor and 22% as very poor habitat, in comparison with reference conditions (Section 7.3).

What is the relationship between the degree of aesthetic quality and remoteness?

- There is a positive correlation between aesthetic quality and remoteness (r^2=0.28) (Section 7.2.5).

13.1.2 Water Chemistry

What % of stream miles in the study area have low pH or acid neutralizing capacity (ANC)?

- An estimated 2.6% of stream miles had spring pH less than 5, while another 6.4% had spring pH 5-6. Summer results were similar: 1.8% of stream miles had summer pH less than 5, while 4.2% had summer pH 5-6. An estimated 28% of stream miles were in low ANC classes, including 2% chronically acidic (ANC < 0 μeq/l), 4% highly sensitive to acidification ($0 \leq$ ANC < 50 μeq/l), and 22% sensitive to acidification ($50 \leq$ ANC < 200 μeq/l). Results varied by basin and stream order, with first-order streams having a greater percentage of stream miles with low pH and ANC (Section 6.2 and Appendix E).

What % of stream miles have high dissolved organic carbon (DOC), sulfate (SO_4), or nitrate-nitrogen (NO_3-N)?

- Statewide, 59% of stream miles had NO_3-N concentrations greater than 1 mg/l, a level indicative of anthropogenic influence. Twenty-nine percent of stream miles had greater than 3 mg/l, and 5% of stream miles had greater than 7 mg/l NO_3-N (Section 8.2 and Appendix E). An estimated 6% of stream miles had DOC greater than 10 mg/l, and 2% of stream miles had SO_4 concentrations greater than 50 mg/l (Appendix E).

What % of stream miles have dissolved oxygen (DO) less than the state water quality standard?

- Statewide, 3% of stream miles had DO concentrations less than 3 ppm. An additional 3% had 3-5 ppm DO (Section 8.2 and Appendix E), falling below the state surface water quality standard of 5 ppm.

What are the geographic distributions of streams with these water chemistry characteristics across the state?

- Low pH and ANC conditions were most common in the Appalachian Plateau and Southern Coastal Plain (Sections 6.2 and 6.4). High NO_3-N was most common in central Maryland and the Eastern Shore (Section 8.2).

What are the average concentrations of these water chemistry parameters across the state?

- The mean statewide NO_3-N concentration was 2.45 mg/l (Section 8.2). Mean NO_3-N was higher, about 4.0 mg/l, among streams in predominantly agricultural watersheds (Section 9.3).

How has the number of acidic and acid-sensitive streams (based on ANC) changed statewide since the 1987 Maryland Synoptic Stream Chemistry Survey (MSSCS)?

- The percentage of acidic and acid-sensitive stream miles was lower in the 1995-97 MBSS (26% of stream miles had ANC < 200 μeq/l), compared with the 1987 MSSCS (33%). The percentage of acidic stream miles was also lower in the 1995-97 MBSS (1.4% of stream miles had ANC < 0 μeq/l) than in the 1987 MSSCS (3.6%) (Section 6.4).

13.1.3 Biological Resources

What % of stream miles in the study area have no fish, non-gamefish, and gamefish species?

- Statewide, an estimated 11% of stream miles had no fish. When very small headwater streams were excluded from this estimate, 4% of stream miles statewide had no fish (Section 4.1.1).

What % of stream miles have exotic species?

- Forty-six percent of stream miles contained non-native fish species. (Section 12.5)

What % of stream miles have rare species?

- Although stream mile percentages were not calculated, the Survey captured six fish, one amphibian, and five mussel species listed by the Maryland Natural Heritage Program as rare. Additional analysis of MBSS data identified nine other fish species that may be considered rare because of their limited occurrence among the sites sampled. Locations of state-listed and other rare fish species were mapped to identify potential areas of conservation importance (Section 12.2).

What is the geographic distribution of fish species across the state?

- Of the 85 fish species collected, three (largemouth bass, bluegill, and pumpkinseed) were found in all basins. On the other end of the spectrum, six basins contained one or two fish species (including johnny darter, striped shiner, flier, shorthead redhorse, stripeback darter, banded darter, Atlantic menhaden, and longnose gar) unique to that basin. Therefore, most fish species were found in more than one, but not all, river basins in Maryland. When the distribution of fish species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—was considered, 51 species occurred in all three regions and less than 10 were unique to any one region (Section 4.1.1 and 12.1.1).

What is the average density (number per stream mile) of individual fish species in the study area?

- The most abundant fishes were blacknose dace, with an average density of 1,970 individuals per stream mile, and mottled sculpin, estimated at 1,370 per stream mile. The most common gamefish species were brook trout (54 per stream mile) and largemouth bass (53 per stream mile). Statewide estimates of density (number per stream mile) and abundance (total number in the study area) for all individual fish species are given in Appendix E (Section 4.1.1 and Appendix E).

Which basins support the highest quality fisheries (i.e., have the greatest number of gamefish above minimum size in first- to third-order streams)?

- The abundance of harvestable-size gamefish was greatest in the Gunpowder basin, with an estimated 23,565 harvestable-size gamefish in first- to third-order streams (Section 4.1.2 and Appendix E).

What % of stream miles in the study area have fish with abnormalities (pathologies and parasites)?

- Forty-four percent of stream miles had fish with pathological anomalies. Two percent of stream miles had gamefish with pathological anomalies (Section 4.1.3).

What % of stream miles have fish with selected types of abnormalities?

- Forty percent of stream miles had fish with skin anomalies, 7% had fish with skeletal anomalies, and 9% had fish with ocular anomalies (Section 4.1.3).

What % of stream miles have selected types of herpetofauna (e.g., frogs and toads, salamanders, and reptiles)?

- Amphibian species (frogs, toads, and salamanders) were the most commonly observed groups, with frogs and toads present at an estimated 44% of stream miles and salamanders present at an estimated 40% of stream miles. Reptiles were less frequently observed: turtles were present at an estimated 7% of stream miles, snakes at 5%, and lizards at 0.4% (Section 4.3).

What is the geographic distribution of reptiles and amphibians across the state?

- In general, the statewide pattern of total amphibian and reptile species richness declines from the western to eastern parts of the State. Only two amphibian (green frog and bullfrog) and one reptile (northern water snake) species were present in all 17 basins. At the other extreme, six basins contained one or two amphibian or reptile species (including Jefferson salamander, northern fence lizard, gray treefrog, redbelly turtle, eastern smooth earth snake, rough green snake, and smooth green snake) unique to that basin. Therefore, most of the 45 amphibian and reptile species collected were found in more than one, but not all, river basins in Maryland. When the distribution of amphibian and reptile species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, 18 occur in all three regions, with the number of species unique to any one region ranging from two in the Coastal Plain to six in the Highlands. Salamander species richness showed the most striking geographic variation, with highest species richness in the westernmost basins (Sections 4.3 and 12.1.3).

Where are additional populations of rare fish and herpetofauna not previously documented located?

- Locations of state-listed and other rare fish species were mapped to identify potential areas of conservation importance (Section 12.2). One rare amphibian species (Jefferson salamander) was found at 1 site in the North Branch Potomac basin (Sections 12.1.3 and 12.2).

To what degree do the flowing, non-tidal waters of the state have balanced indigenous populations of biota as measured by the fish community (e.g., What is the % of stream miles in degraded condition based on the Index of Biotic Integrity (IBI))?

- Statewide estimates based on the fish IBI indicate that 20% of stream miles were in good condition, 25% fair, 15% poor, and 14% very poor condition. A total of 74% of stream miles (all but the smallest headwater streams, where few fish are expected) were rated using the fish IBI (Section 5.3.1).

To what degree do the flowing, nontidal waters of the state have balanced indigenous populations of biota as measured by the benthic macroinvertebrate community (e.g., What is the % of stream miles in degraded condition based on EPT taxa, Hilsenhoff Biotic Index, or Benthic Index of Biotic Integrity)?

- Statewide estimates based on the benthic IBI indicate that 11% of stream miles were in good condition, 38% fair, 26% poor, and 25% very poor condition (Section

5.3.2). Assessments based on the Hilsenhoff Biotic Index showed that 33% of stream miles were in good condition, 37% fair, 14% poor, and 2% very poor condition (Section 5.3.3).

13.1.4 Landscape Characteristics

What % of area (acres) in the study area is in the following land use categories: agriculture, forest, urban, and wetlands?

- To quantify land uses that may affect streams sampled, the Survey characterized land uses within the watersheds upstream of each site. Statewide, the dominant land use in these site-specific catchments was forest (with a mean percent cover of 46%), followed by agriculture (44%) and urban (9%). On average, wetlands made up only a small fraction of catchment areas (Section 9.2).

What is the geographic distribution of these land use categories in the study area?

- The diversity of land uses in Maryland can be seen in a statewide map (Section 3.5). Within individual basins, agricultural land use was greatest at sites in the Susquehanna basin (with a per-site mean of 66%) and in the Middle Potomac, Gunpowder, and Elk basins (all 63%). Sites in the North Branch Potomac had a mean of just 15% agriculture, while the mean in the remaining basins ranged from 22 to 60% agricultural land. Forest cover was most extensive for sites in the North Branch Potomac basin (83%) and least extensive in the Patapsco basin (1996 sampling, 21%). As expected, urban land use was greatest in the Patapsco (31%) and Potomac Washington Metro (23%) basins. Four basins–Patuxent, West Chesapeake, Patapsco (1995 sampling), and Bush–had a mean percentage of urban land use between 10 and 20%. The remaining basins had a mean percentage of urban land use less than 10%. In all basins, wetlands accounted for less than 5% of catchment land area (Section 9.2).

Where are the minimally affected streams and what are their land use/landscape characteristics?

- Minimally-affected streams (those receiving good to fair ratings by the fish and benthic IBIs) were located throughout the state (Section 5.3). Further analysis of sites rated as good by the fish IBI showed that these streams were generally characterized by less urban development. Sites rated as good by the fish IBI had an average of 4% urban land use, compared with an average of 9% for all sites (Section 9.4.1)

13.1.5 Resource-stressor Associations

What % of chronically acidic stream miles in the study area are associated with acid mine drainage (AMD) or acidic deposition as measured by pH, ANC, and SO_4?

- Among chronically acidic stream miles (those with ANC < 0 μeq/l), acid mine drainage was the dominant source of acidification in 38% of stream miles and acidic deposition was dominant in 42%. Organic acids influenced 9% of chronically acidic streams, while another 11% were influences by both organic ions and acidic deposition (Section 6.3).

What is the relationship (subpopulation analysis or correlation) between water chemistry (ANC, pH, DOC, SO_4, NO_3, and DO) and abundance of fish species?

- Fish species richness and density (number of fish per stream mile) declined at low-ANC sites. Also, fish IBI scores showed a decline with low ANC and low pH, with IBI scores dropping into the poor range at pH 5-6 (Section 6.5). For individual species, dramatic declines were seen in fish species composition and abundance in low ANC classes (Section 6.7).

What is the relationship between stream channelization and the abundance of fish species?

- Fish IBI scores decreased with low scores for channel alteration (Section 7.5).

What is the relationship between riparian buffer and the abundance of fish species?

- Fish IBI scores increased at sites with greater riparian buffer width (Section 7.5).

What is the relationship between remoteness and abundance of fish species?

- Remoteness was strongly related to the abundance of brook trout. Among remote sites, density was estimated at 138 brook trout per stream mile, compared with 36 individuals per stream mile at non-remote sites (Section 7.5).

What % of stream miles in the study area have suitable physical habitat and would be expected to have desired species (e.g., gamefish or endangered species) if water chemistry or other stressors were absent (i.e., are candidates for restoration)?

- Statewide, 20% percent of stream miles were rated as good and 29% fair by the PHI, indicating together that about half of the stream miles in the State are comparable with reference conditions for physical habitat (Section 7.3).

13.1.6 Resource-landscape associations

What is the relationship between land use and stream resources using indices of the biological community such as the IBI?

- Statewide, both the fish and benthic IBI decreased with increasing amounts of watershed urbanization, whether measured as all urban land, low-intensity, or high-intensity urban only. Benthic IBI scores increased with the percentage of catchment area in forest cover. The IBIs were less effective in detecting effects of agriculture at the watershed scale. The Hilsenhoff Biotic Index increased (indicating degradation) with both urban and agricultural land use and was negatively correlated (indicating better conditions) with the amount of forest cover. In many cases, by reducing variability, relationships within individual basins provided a clearer picture of land use relationships than did statewide results (Section 9.4).

13.1.7 New Questions

What is the quantity of available physical habitat in streams within the study area, in terms of width, depth, discharge, and amount of woody debris?

- Statewide, the mean stream width was 3.4 m and mean thalweg depth (depth at the deepest part of the channel) was 22 cm. Stream discharge, which tends to increase with watershed area, stream width, and depth, had a mean value of 2.7 cubic feet per second (cfs). The mean number of rootwads and other woody debris was 4 pieces per 75-m stream segment. As expected, values for habitat quantity varied by basin and stream order (Section 7.2.6).

How do the geographically diverse MBSS data compare with data from DNR's CORE/Trend monitoring program (a less extensive but long-term sampling effort)?

- In a comparison of nutrient data, the statewide mean nitrate-nitrogen concentration from the MBSS data was 2.45 mg/l, while CORE/Trend samples from the same time period (spring 1995-97) had a mean of 1.82 mg/l. Mean NO_3-N concentrations in the Youghiogheny and the North Branch Potomac basins were both consistently low, showing little difference between monitoring programs. However, differences were more apparent in other basins, and Spearman correlation analysis showed that basin NO_3-N concentrations were ranked differently by the two monitoring programs. Differences between the two programs may be explained in part by differences in sample site locations and stream size.

How do MBSS results for stream chemistry, physical habitat, and biological communities vary from year to year, and do differences correspond with annual changes in weather conditions?

- Within the three basins resampled by the Survey in two different years (Youghiogheny, Patapsco, and Choptank), the mean value in each sample year for the fish IBI, benthic IBI, PHI, and nitrate-nitrogen concentration were examined. Although some small differences were detected, virtually all were within the range of error (±1 standard error). Statewide, Maryland received an average of 38% more rainfall than normal in 1996, while 1995 and 1997 each received an average of 7% less rainfall than normal. However, the large amount of rain that fell in 1996 did not result in predictably lower (or higher) values for any of the parameters examined (Chapter 10).

Which stressors are most extensive throughout the state?

- The most extensive source of stress was physical habitat degradation, which affected an estimated 52% of stream miles. Riparian vegetation was lacking from 28% of stream miles. Agricultural land uses were influential at 17% of stream miles, while urban land use was a potential stress at 12% of stream miles. Nutrient concentrations were high in 5% of stream miles statewide. Acidic deposition affected an estimated 21% of stream miles, while acid mine drainage affected 3% of stream miles (Section 11.1).

What site-specific information can the Survey provide to detect stream degradation and identify sources of stress at particular locations?

- To screen sites, the fish IBI and benthic IBI were used to identify individual sites with low biotic integrity. Statewide, 203 sites were rated as poor to very poor for both IBIs, and another 336 rated poor to very poor for either the fish or benthic IBI. For each site, site information and physical and chemical parameters indicative of potential stressors were compiled to facilitate further investigation (Section 11.3 and Appendix F).

In addition to species listed by the Maryland Natural Heritage Program, what fish species might be considered at risk, based on low frequency of occurrence in MBSS sampling?

- Survey data were used to identify freshwater fish species occurring at the lowest frequency. In addition to six Heritage-listed fish species, there were nine other fish species that occurred just as infrequently and could also be considered at risk in Maryland streams; rainbow darter, comely shiner, striped shiner, American brook lamprey, checkered sculpin, warmouth, pearl dace, johnny darter, and swamp darter (Section 12.2).

What is the distribution of non-native mussel and fish species?

- Asiatic clams were found in 13 of the 17 river basins sampled, although they were found in relatively few sites in each basin. The zebra mussel was not found during 1995-1997 MBSS sampling. Non-native fish species were found in all basins (Section 12.5).

What % of stream miles in a particular watershed or county have streams in good, fair, or poor condition according to the biological and physical habitat indicators?

- A pilot analysis of biological and physical habitat indicator results for selected watersheds and counties was conducted to demonstrate the utility of MBSS data for calculating estimating condition at these finer scales (Section 13.2.5).

13.2 RELEVANCE TO CURRENT MANAGEMENT AND POLICY INITIATIVES

Information from the Survey is already being used to support management and policy initiatives at DNR. Specifically, the answers to the questions presented in the preceding section are helping DNR managers and policymakers to address the primary objectives of the MBSS:

- assess the current status of biological resources in Maryland's non-tidal streams;

- quantify the extent to which acidic deposition has affected or may be affecting biological resources in the state;

- examine which other water chemistry, physical habitat, and land use factors are important in explaining the current status of biological resources in streams;

- compile the first statewide inventory of stream biota;

- establish a benchmark for long-term monitoring of trends in these biological resources; and

- target future local-scale assessments and mitigation measures needed to restore degraded biological resources.

By addressing these objectives, the Survey supports a wide range of current management and policy initiatives at Maryland DNR and other agencies. For example, the Survey provides DNR with (1) a targeting tool that is statewide, (2) a baseline to use when designing future monitoring programs, and (3) data that can be used in an integrated way to assess cumulative impacts. The following sections describe specifically how the principal results of the 1995-1997 MBSS are contributing to current natural resource and environmental programs.

13.2.1 Inventory of Maryland’s Aquatic Resources

DNR’s mandate is to effectively manage the natural resources of the state. It is axiomatic, therefore, that DNR needs to know what these resources are, where they occur, and how abundant they are. Aquatic ecosystems, and streams in particular, are an abundant and diverse resource not easily characterized. With the completion of the 1995-1997 MBSS, DNR has its first comprehensive picture of Maryland’s stream resources.

From MBSS data, we know that more than 8,000 miles of streams run through the state and that approximately 60 million fish live in these streams. More importantly, we have improved our knowledge of where individual species, including recreationally important and rare species, exist. We also know the extent and geographic distribution of physical features and water chemistry parameters that describe both natural variation and human influences. Such knowledge is the first step in developing new holistic approaches to assessment and practical strategies for the management of natural resources.

The Monitoring and Non-Tidal Assessment (MANTA) Division of DNR is charged with building the knowledge base on Maryland's stream resources and is using the MBSS (among other programs) to do so. The results of the Survey to date have enabled DNR to plan strategies and set stewardship goals not possible previously. At the same time, the experience of implementing the Survey and the results themselves are being used by MANTA to design future monitoring and assessment programs leading to a statewide water monitoring strategy.

Several other parts of DNR are making use of MBSS data. The Fisheries Service has the critical role of managing fisheries resources and enhancing fishability throughout the state. The Survey's statewide and basinwide estimates for each fish species can be used to supplement Fisheries Service data and better target management efforts. As one example, information on basins that have at-risk populations of brook trout can be used to focus future fisheries management decisions.

While gamefish populations are of interest to DNR and the public, both entities also place substantial value on maintaining and enhancing the state's aquatic biodiversity. The Heritage and Biodiversity Conservation Programs of DNR are charged with identifying and conserving rare species and other components of Maryland biodiversity. The Survey provides statewide, statistically rigorous data on the abundance and distribution of fish (and to a lesser degree other organisms) that can be used to validate and supplement natural heritage program information. Results of the 1995-1997 MBSS confirm the status of species listed as rare by the natural heritage program, while providing evidence for consideration of other species potentially at risk. Information on concentrations, or hotspots, of biodiversity components (rare fish species collected by the Survey are concentrated in five regions of the state) are already being used to support PPRP's Smart Siting initiative and DNR's Unified Watershed Assessment.

The information on the abundance and geographic distribution of stream resources, especially aquatic biota, is valuable for many other groups with mandates for or interests in protecting Maryland's streams. These include the U.S. Fish and Wildlife Service, Biological Resources Division of USGS, U.S. Army Corps of Engineers, and U.S. Environmental Protection Agency's Mid-Atlantic Integrated Assessment. Maryland counties and private organizations, such as Save Our Streams, are also using MBSS data.

13.2.2 Current Condition of Maryland's Streams

Perhaps the most important information for a natural resource manager is—What is the condition of the resource? This information is critical to answering the questions of (1) where Maryland's stream problems are, (2) what they are, and (3) how can they be fixed.

With the completion of the 1995-1997 MBSS, DNR has its first comprehensive picture of the condition of stream resources. The critical step in describing stream condition was appropriately defining "stream degradation" and developing the indicators needed to measure it. Consistent with current ecosystem-based approaches, the Survey defines degradation as "loss of biological integrity based on deviation from reference condition." Therefore, one of the key accomplishments of the Survey was the development of two reference-based biological indicators—the fish IBI and benthic IBI— that could be used to identify degradation anywhere in the state.

The benthic IBI indicates that approximately one-half of all Maryland streams are in poor or very poor condition. Somewhat fewer streams are poor or very poor according to the fish IBI. The estimated proportion of streams that are degraded statewide, or within a specific river basin, depends on the threshold chosen. The Survey has chosen the low end of reference values (values that capture approximately 10% of reference sites) to signify degradation, although streams marginally above this level are rated as "fair." By effectively quantifying stream condition, these indicators provide a valuable tool for setting protection levels and forming restoration targets.

As a specific example, DNR incorporated mean values by 8-digit Maryland watersheds for both the fish IBI and benthic IBI in the State's Unified Watershed Assessment required under the Clean Water Action Plan. These indicators provided some of the best biologically based information provided to EPA by any state. These IBIs were used with other indicators to help designate both Category 1 (priorities for restoration) and Category 3 (priorities for protection) watersheds within Maryland.

In addition to supporting DNR's management programs, the identification of degraded stream segments has implications for protection under the Clean Water Act. Section 101 of the Act states that physical, chemical, and biological integrity of waters should be maintained. Stream segments that fail to do this can be designated as degraded and not attaining designated uses as part of their water quality standards. The Maryland Department of the Environment

(MDE) implements the water quality standards program and prepares a 303d list of streams not meeting their designated uses. Streams rated as poor or very poor by MBSS data are candidates for listing on the 303d list. Ultimately, total maximum daily loads (TMDLs) must be developed for streams on this list; in the case of MBSS-rated streams, additional monitoring may be needed to verify degradation and determine the specific cause and how it can be controlled.

As MDE moves forward with development of biological criteria to support their water quality standards program, the MBSS biological indicators will likely be a primary focus. Incorporating quantitative, reference-based indicators (such as the MBSS fish IBI and benthic IBI) into criteria is consistent with current EPA guidance.

Assessments of stream condition based on the survey's ecological indicators were also provided to the State's Tributary Strategies program. Estimates were calculated for each of the state's 10 Tributary Strategies basins, which are aggregations of the 17 major river basins used by the survey (Figure 13-1).

13.2.3 Trends in the Condition of Maryland's Streams

One of the most frustrating problems facing natural resource and environmental managers is the lack of historical monitoring data against which to compare current monitoring results. Determining the change in a resource over time is often essential to understanding its condition and prospects for future decline or improvement. One of the most important reasons for conducting the 1995-1997 MBSS was to provide a comprehensive, statewide baseline for future monitoring efforts. Now that it is complete, DNR has many options for future monitoring that can address short-term and long-term trends.

Determining trends, or change over time, can answer three important questions: (1) is the resource stable, declining, or improved in comparison to desired conditions? (2) is the resource declining in response to changes in specific stressors? and (3) is the resource improving in response to specific management measures? While the answers to the questions must generally await a second round of monitoring, some trends questions are currently being addressed.

The Survey had the specific goal of determining whether the extent of acid-sensitive streams in Maryland had changed since the 1987 Maryland Synoptic Stream Chemistry Survey (MSSCS). Results indicate that the proportion of streams with less than ANC of 200 µeq/l has dropped slightly from 33% to 26%. This information can be compared with air emissions data from EPA and with acidic deposition data from the National Acid Deposition Program; current results and future trends have important implications for assessing the effectiveness of controls instituted as a result of the 1990 Amendments to the Clean Air Act.

Future trends detection using the MBSS baseline monitoring data will likely prove invaluable for addressing two areas of projected change in Maryland: (1) continued population growth and the land use changes that will accompany associated development and (2) climate change. The Governor's Smart Growth plan is a promising solution to contain sprawl development and degradation of the landscape, but monitoring of trends in resource condition will be needed to determine if it is being implemented effectively. Lastly, the current baseline of stream monitoring data should be incorporated into monitoring the effectiveness of specific restoration projects to be funded under the Clean Water Action Plan and other initiatives.

13.2.4 Impacts of Human Activities on Maryland's Streams

While reliable information on the condition of Maryland's streams is critical to effective management, problems cannot be remedied unless we know their causes. For this reason, the Survey did not restrict itself to biological sampling; water chemistry, physical habitat, and other parameters related to possible stressors were included. By collecting all these parameters in conjunction with biological data at each stream site, the Survey can make accurate estimates of the relative contributions of different stressors and begin to investigate the cumulative effects they have across the landscape.

MBSS results indicate that physical habitat degradation is the most pervasive source of stream problems, affecting 52% of stream miles in the state; in descending order of extent of stream miles affected, other important stressors are lack of riparian vegetation (28%), acidic deposition (21%), agriculture (17%), urbanization (12%), nutrients (5%), and acid mine drainage (3%). This confirms that while acid mine drainage effects may be severe on individual streams, acidic deposition affects many more streams. MBSS results also indicate that many streams are affected by a combination of stressors, all of which need to be considered to assess the cumulative impact of human activities.

Foremost among the widespread stressors are physical habitat degradation and the agricultural and urban land uses that contribute to adverse effects. The Physical Habitat Index developed by the Survey (in a manner analogous to the IBIs) provides a means of differentiating natural variation from human influence on this critical parameter. Analysis of the MBSS results has identified important associations between many stressors and the fish and benthic IBIs. For example, fish and benthic IBIs decline steadily with increasing amount of urban land; while at the same time these IBIs increase with increasing habitat quality (as determined by the Physical Habitat Index). The use of these rigorous biological indicators is a powerful tool for investigating relationships with potential stressors. This approach can be expanded to individual species to delineate environmental preferences, such as sensitivity of brook trout to impervious surfaces that exceed 2% of the watershed (although the confounding effects of geographic correlations between stressors and natural variation need to be considered). Association analysis can also be used to help segregate synergistic or antagonistic effects among stressors. For example, stream nutrient concentrations (as measured by nitrate-nitrogen) concentrations remain relatively stable in watersheds of up to 50% agricultural land, but then concentrations increase substantially with higher proportions of agricultural land.

Ultimately, solutions to stream problems depend on effective restoration at the source of degradation. Within DNR, the Integrated Natural Resource Assessment is collecting stressor information at a watershed scale. Information on the relative importance of stressors is also used by EPA's Mid-Atlantic Integrated Assessment. As the environmental regulatory agency, MDE can use MBSS stressor information to identify industry sectors and land management practices that need further controls. As mentioned above, preliminary stressor information associated with specific degraded stream segments can be used to target additional monitoring leading to listing as 303d streams and subsequent development of TMDLs. This 1995-1997 MBSS report includes a table of 539 degraded stream sites with the associated values for 32 potential stressors. Nutrient contributions from streams can be used by the Tributary Strategy Teams as they develop nutrient reduction plans to meet Chesapeake Bay restoration goals. MBSS nutrient information, as well as data on fish abnormalities, can also help better understand the role of streams on outbreaks of *Pfiesteria* and other toxic organisms.

13.2.5 Targeting Restoration Efforts within Maryland

Selecting, designing, and implementing watershed restoration efforts will, in large part, determine the success of DNR's management of Maryland's stream resources. Many questions of public policy will be involved and are outside the realm of environmental assessment and scientific inquiry. In particular, the many uses desired by the public and the values they place on individual resources will affect the management and policy decisions made by DNR and other regulatory and management agencies. Each restoration effort will begin with a goal that defines the desired condition the project is trying to obtain. Whether conditions comparable to those prior to European settlement are appropriate for some or many parts of the state remains to be determined. Just what alternative conditions may be acceptable in developed areas and what ecological functioning can be sustained are also unknown. Regardless of the answers to these questions, science has an increasing role to play in supplying the public with information; now that individual citizens and organized interest groups are engaged in efforts to manage natural resources it is critical that they not be swayed by anecdotes that are not supported by evidence. Scientific information must be at hand when opportunities for major management and policy decisions arise.

The Survey was designed to produce accurate estimates of the extent of stream features, degraded streams, and potential stressors at the statewide and river basin scales. While the 1995-1997 sampling has accomplished this, natural resource managers ultimately need monitoring results on a finer scale. In particular, each of Maryland's 22 counties has boundaries different from the 17 river basins and generally needs a higher density of sample sites. DNR has committed in its Integrated Natural Resource Assessment to characterize watersheds at the 8-digit scale (138 in Maryland) for targeting and planning purposes. The state's 138 watersheds are subunits of the 17 major basins used by MBSS (Figure 13-2; Appendix G). When detailed restoration and management plans are developed, information at the 12-digit watershed scale (1166 in Maryland) may be needed. Beyond this, local scale implementation may require assigning values to entire stream reaches, through an adaptive sampling approach or supplemental field reconnaissance. To demonstrate the utility of existing MBSS data at these finer scales, two sets of estimates are provided as a sidebar to this section—(1) estimates for all Maryland counties and (2) estimates for six small watersheds covering a range of sample density (5 to 36 sites in each).

As described above, data from the 1995-1997 MBSS were incorporated into the Integrated Natural Resource Assessment by DNR's Watershed Management and Analysis Division and used to produce the Unified Watershed Assessment submitted to EPA under the Clean

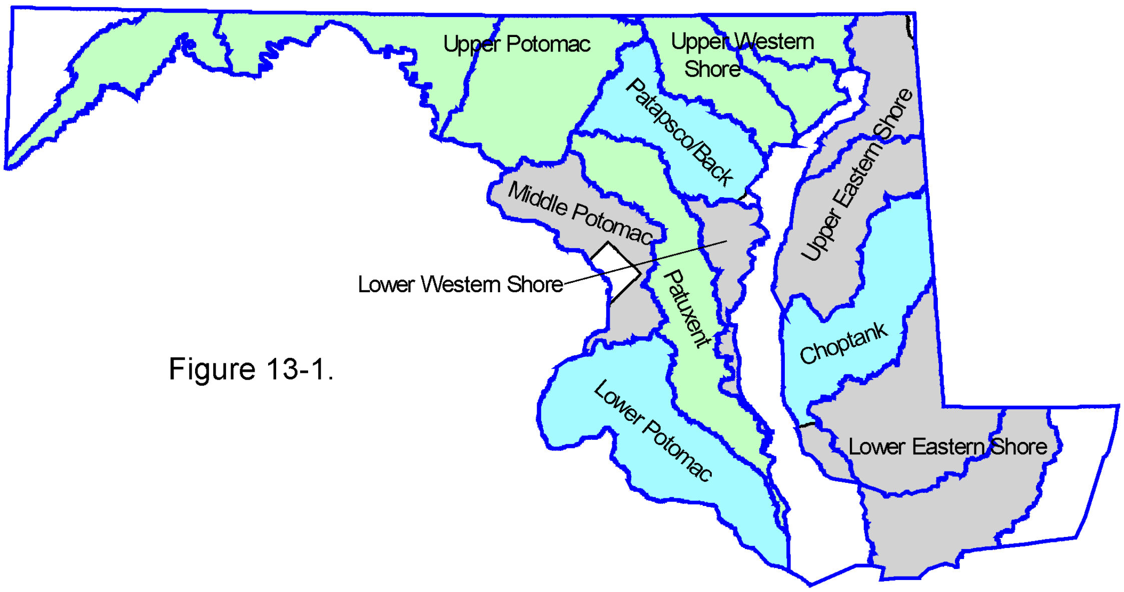

Figure 13-1.

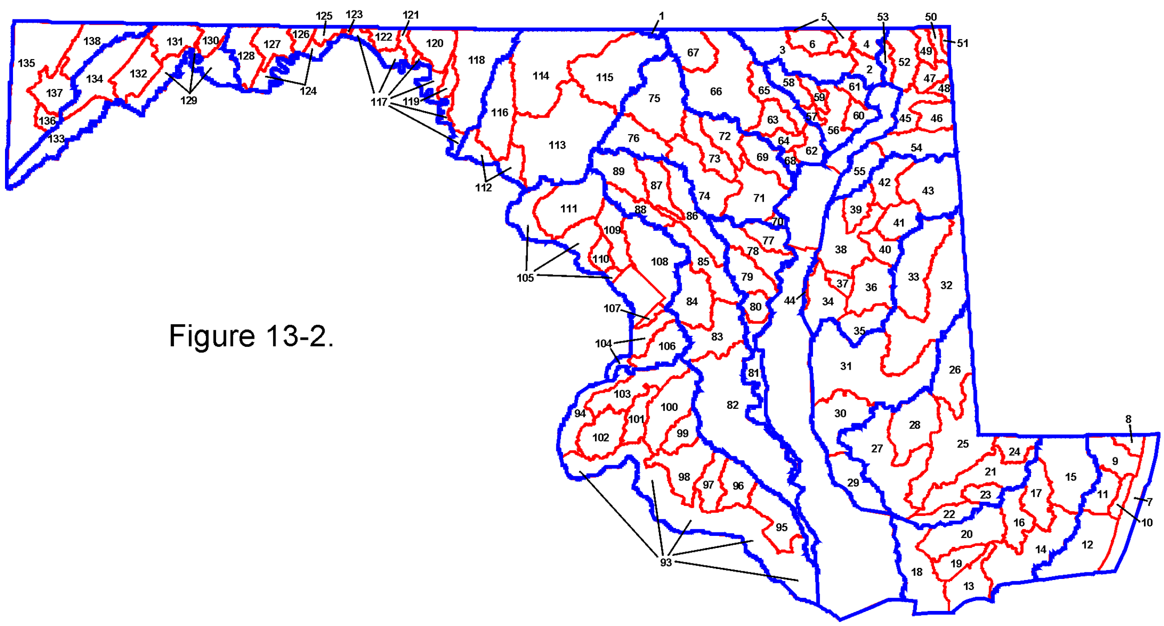

Figure 13-2.

Figure 13-1. Maryland's 10 Tributary Strategies basins. The blue lines show the boundaries of the major river basis used in MBSS reporting.

Figure 13-2. Maryland's 138 8-digit watersheds (in red) within the major river basins used in MBSS reporting (blue)

Water Action Plan. This process has assigned watershed scores to each of the 138 watersheds (excluding those in the Chesapeake Bay) designating its priority for restoration (Category 1). Those watersheds receiving the highest scores for both restoration (Category 1) and protection (Category 3) were selected as highest priority—a total of 11 watersheds. These will be a focus of 1999 restoration efforts by DNR's Watershed Restoration Division under the Clean Water Action Plan and other initiatives.

As an example of further targeting efforts, the Governor has committed to restoring 600 miles of riparian vegetation in Maryland (to meet the "2010 miles of riparian buffer by 2010" Chesapeake Bay watershed goal). Figure 13-3 illustrates the percentage of stream miles in each Maryland river basin that has 19 m of riparian buffer vegetation. This demonstrates that the need for restoring riparian vegetation is greatest in certain basins, e.g., the Patapsco and Middle Potomac. At the same, managers recognize that a watershed approach that addresses total land use composition in addition to riparian reforestation is needed for effective restoration (Center for Watershed Protection 1998). A critical consideration for managers targeting riparian plantings or other stream restoration efforts is the composition and distribution of land ownership across the state.

Information collected by the Survey while contacting landowners for permission to access sampling sites was used to estimate the extent of public (parks, federal facilities, and other state, county, and local government land), private (owned by individuals or businesses), and mixed (both public and private) ownership of land adjacent to stream sites. Individual site data were used to estimate the areawide extent of each type of ownership. A large majority of streamside land is in private ownership (Figures 13-4 and 13-5). Statewide, an estimated 79% of stream miles are on private land, while only 17% are public. Within some individual basins, the extent of private ownership is even higher, with private land encompassing greater than 90% of stream miles in the Choptank and Pocomoke basins. Even among the public lands in Maryland, many areas currently do not provide substantial protection for natural resources. Figure 13-6 illustrates the smaller subset of protected lands, that themselves include open space dedicated to multiple uses. Public lands that are not currently managed for natural values may offer the best opportunities for new restoration efforts. In any case, the predominance of private land ownership in Maryland indicates that natural resource managers will have to work effectively with local land use planners, and private property owners to effect substantial stream and watershed restoration.

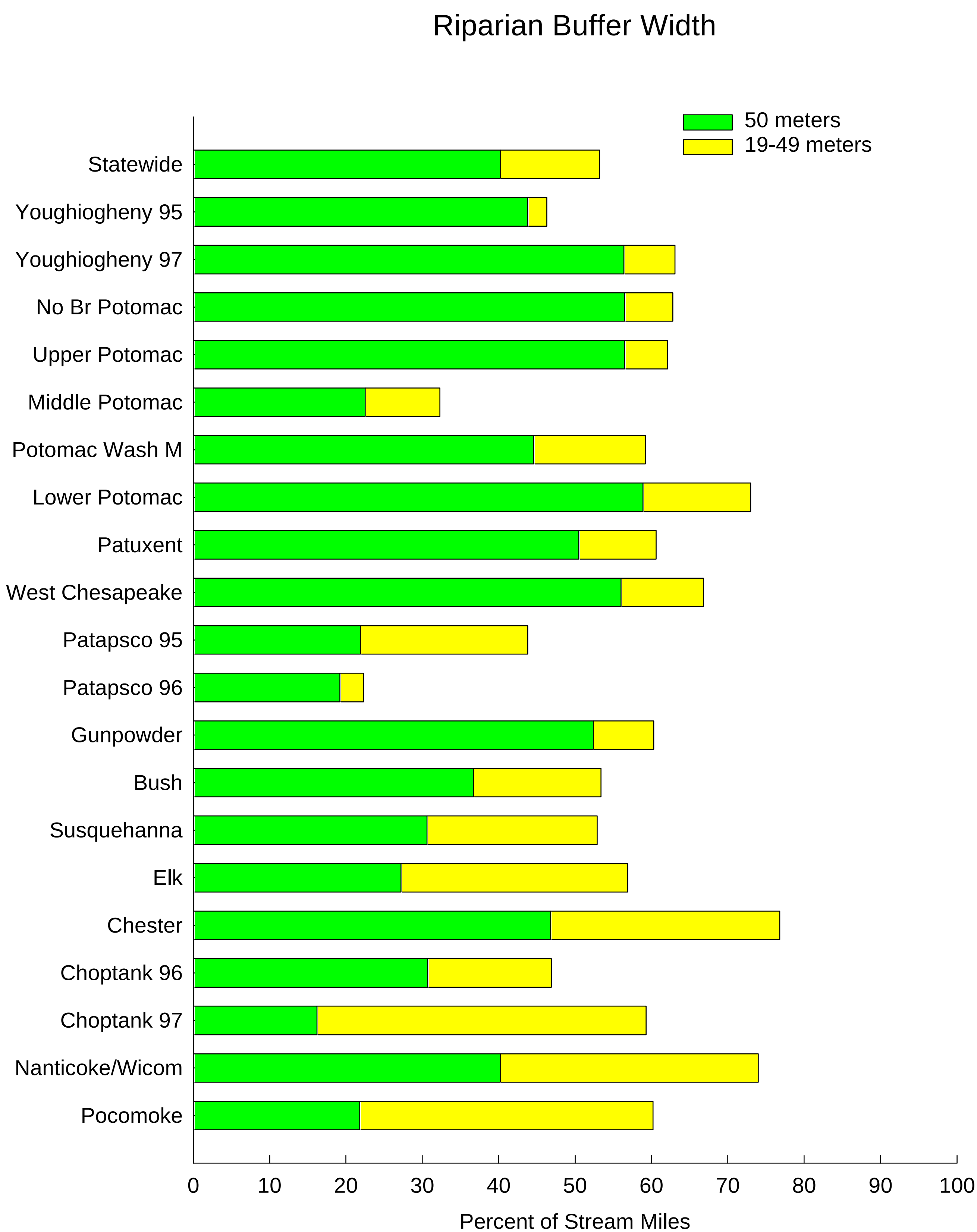

Figure 13-3. Percentage of stream miles with riparian buffer width 19-50 m, statewide and for the basins sampled in the 1995-1997 MBSS

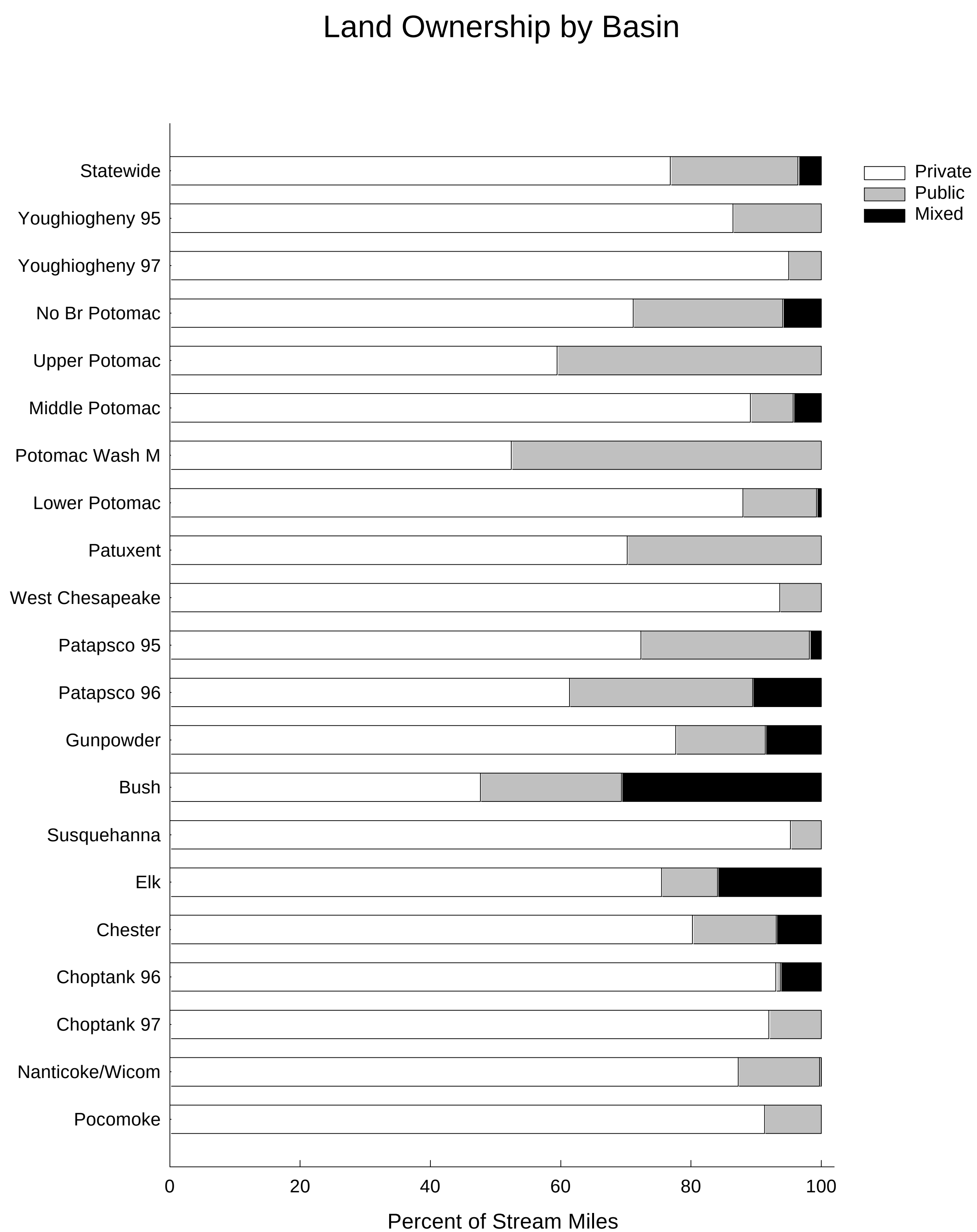

Figure 13-4. Percentage of stream miles that are located on public, private, or mixed ownership land, statewide and for the basins sampled in the 1995-1997 MBSS

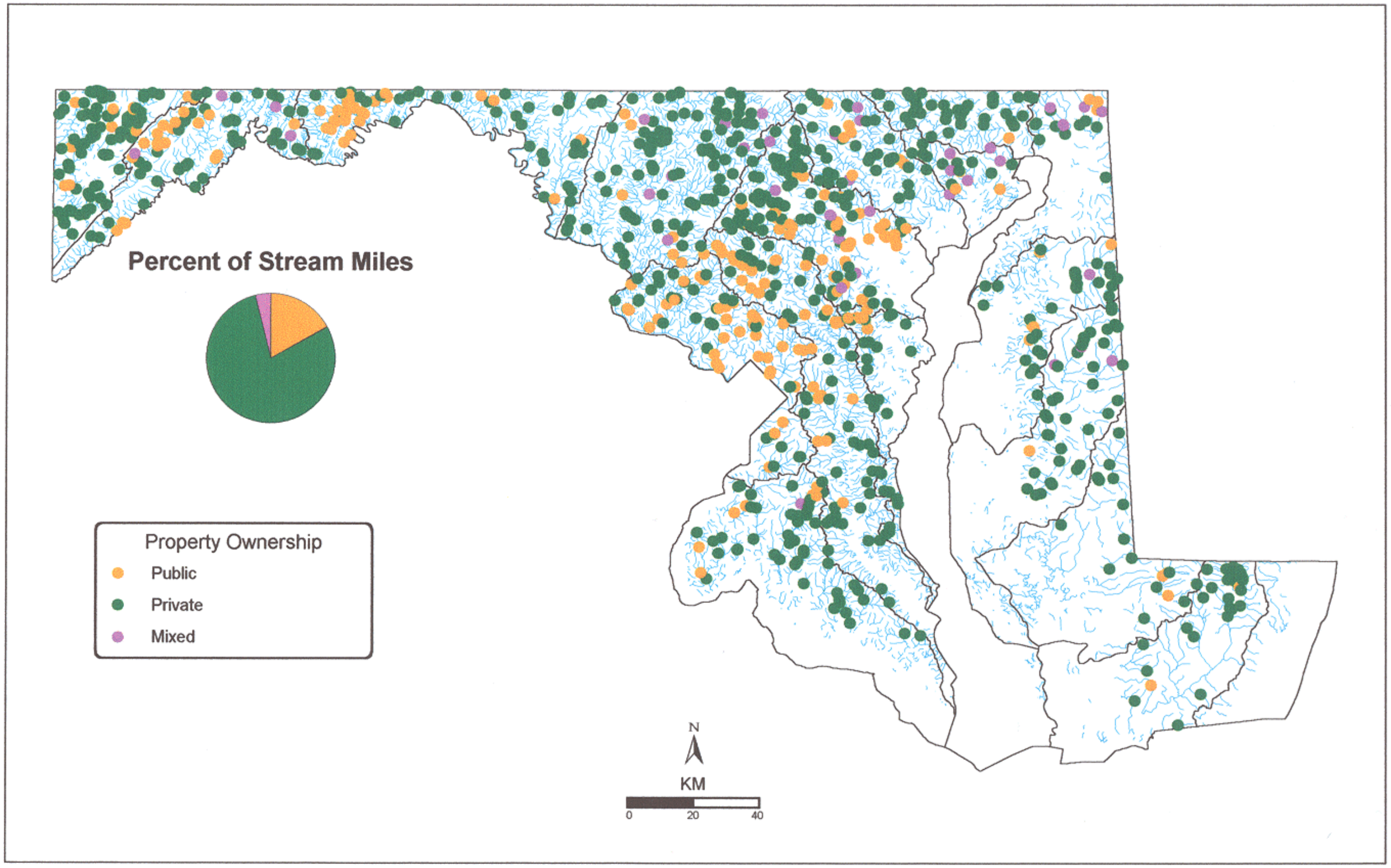

Figure 13-5. Geographic distribution of 1995-1997 MBSS sites that are located on private, public, or mixed ownership land. The pie chart indicates the statewide percent of stream miles in each ownership category.

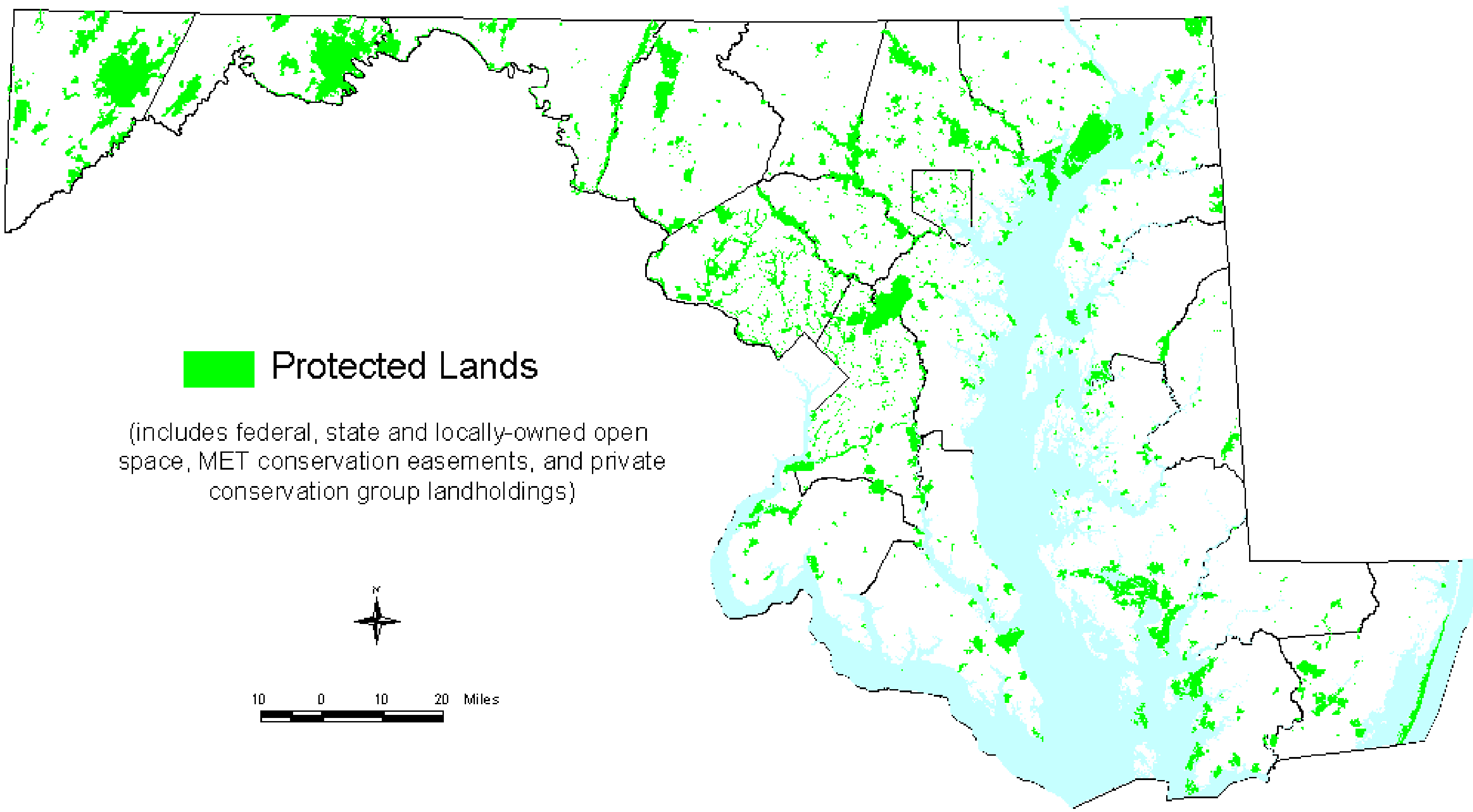

Figure 13-6. Geographic distribution of protected lands

MBSS County and Watershed Estimates

While the 1995-1997 MBSS was designed to make estimates of stream condition statewide and within the 17 major drainage basins in the state, natural resource managers and policymakers may desire MBSS information on a smaller scale, such as the county or Maryland 8-digit watershed level. Towards this purpose, estimates of the fish and benthic IBIs, as well as the Physical Habitat Index were made for the 24 counties in Maryland (including Baltimore City) and for six selected watersheds throughout the state (Appendix H). A discussion of both countywide and watershed-scale information will be included in future reports.

The fish and benthic IBI scores in five selected counties – Anne Arundel, Baltimore City, Garrett, Montgomery, and Wicomico – are presented in Figure 1. In highly urbanized Baltimore City, the vast majority of stream miles were rated very poor by both the fish and benthic IBI (77% and 97%, respectively). In contrast, Garrett County, a rural county located in western Maryland, the greatest percentage of stream miles was rated good by both the fish and benthic IBI (26% and 28%, respectively). It is important to note that (approximately 25%) of stream miles in Anne Arundel, Garrett, and Montgomery Counties were not assigned a fish IBI score because of small watershed size, supporting the need for a separate indicator for small streams.

The fish and benthic IBIs in four of the six watersheds (selected to provide a range of sample site densities) are presented in Figure 2. Streams in the Deep Creek Lake watershed, located in western Maryland, were in the worst condition according to the fish IBI (63% of stream miles were rated very poor and the remaining 37% were not rated). Gwynns Falls, a watershed located in the Baltimore-Washington corridor, was in the worst condition according to the benthic IBI (57% of stream miles rated very poor). Mattawoman Creek was in the best condition according to both the fish and benthic IBIs (44% and 18%, respectively).

It is important to note that many countywide and watershed-scale estimates of the fish and benthic IBIs and the Physical Habitat Index, had standard errors greater than 100%. This results from the small number of sample sites in many counties or watersheds (see Table H-4). For example, given the six sites were sampled in the summer in Worcester County, forty-six percent of stream miles were rated good using the fish IBI, but the standard error of that estimate was 107. If more precise estimates at these or other fine scales are desired, future MBSS sampling may have to target higher sample densities. It is also important to note that the absence of the smallest streams from the 1995-1997 MBSS sample frame may bias the estimates of condition in watersheds with many small streams such as Deep Creek. The second round of the Survey plans to use a more detailed sample frame to capture more small streams.

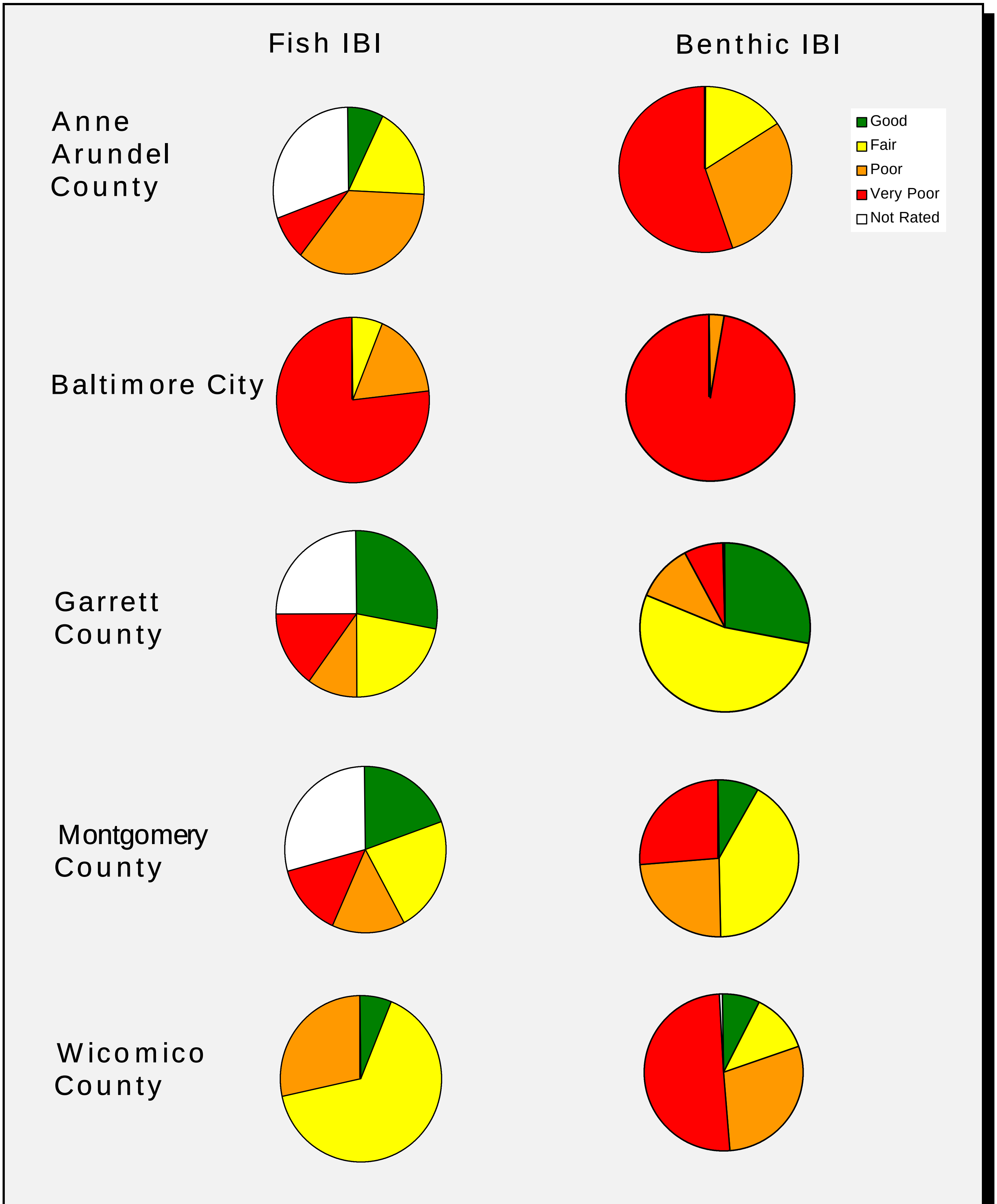

Figure 1. Percentage of stream miles rated good, fair, poor, and very poor by the fish and benthic Indices of Biotic Integrity (IBIs) for five selected Maryland counties

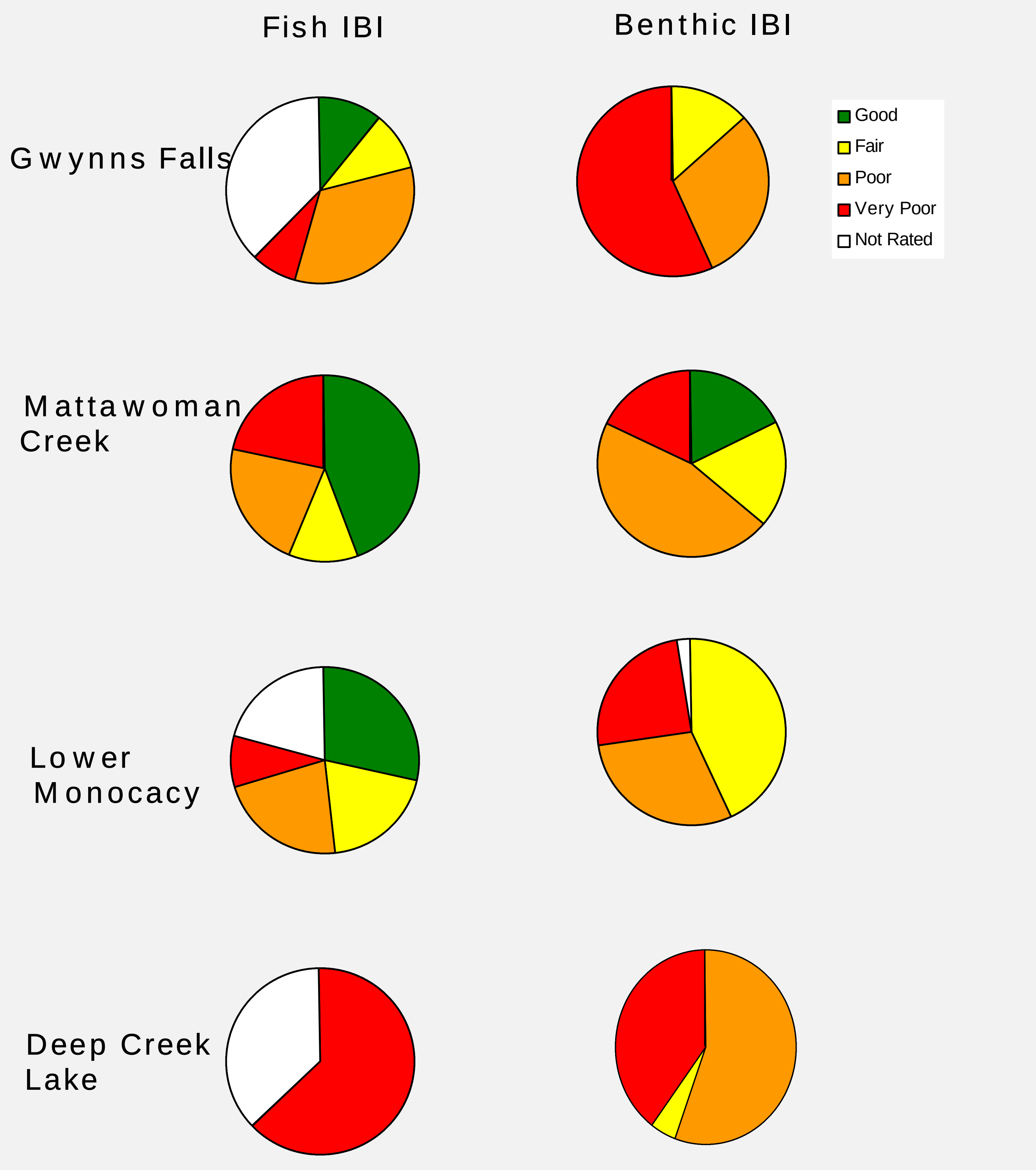

Figure 2. Percentage of stream miles rated good, fair, poor, and very poor by the fish and benthic Indices of Biotic Integrity (IBIs) for four selected Maryland watersheds (Maryland 8-digit code)

14 FUTURE DIRECTIONS FOR THE MBSS

The success of the 1995-1997 MBSS has encouraged DNR to continue its stream monitoring. DNR has begun planning for a second round of the Survey by developing a new set of management questions that reflect what has been learned in the first round of the Survey, as well as the evolution of management and policy concerns since 1995. To this end, the Monitoring and Non-Tidal Assessment Division has solicited comments from all parts of DNR on a draft set of management questions and will use these responses to help determine whether design changes or method refinements are warranted.

Most of the original 64 MBSS questions that have not yet been answered dealt with identifying potential stressors using data not collected as part of the Survey. Much of this information can be gathered from other sources and linked to MBSS sites so that statewide estimates can be made of stressor extent (e.g., number of stream miles with point sources of contamination, amounts of pesticides applied by geographic area, or pattern of landscape patches in upstream catchments). A few of the original management questions are impossible to answer with current data; some others are of only minor interest.

New management concerns likely to be incorporated into the next round of MBSS monitoring fall into the following categories:

- Comparing among sample rounds for detection of trends
- Extending into smaller and larger streams, while delineating more stream types
- Characterizing and assessing at finer geographic scales
- Better characterizing existing and new stressors
- Refining existing indicators and developing new ones
- Improving identification of rare species and other biodiversity components.

14.1 TRENDS DETECTION

As mentioned earlier, one of the main reasons for implementing the 1995-1997 MBSS was to create a baseline for comparison with future monitoring results. Therefore, it is critical that the second round of MBSS sampling is designed to take full advantage of this baseline. One of the most promising approaches is to include a subset of fixed sites (i.e., sites sampled during the 1995-1997 MBSS) among a larger set of random sites that can still provide areawide estimates. This type of design is generally referred to as partial replacement.

An important factor in evaluating potential trends is natural interannual variability. Some investigators have reported dramatic changes in stream biota with unusual precipitation events, although this is not always the case. Using the 1995-1997 results from basins sampled in two years and from repeat visits to selected sites, we have an preliminary assessment of the magnitude of this variability. This information will be used to determine how the power to detect trends will vary with the frequency of and density of samples.

Trends in natural resource condition are most useful if they can be related to associated trends in specific stressors or human influences in general. In future years, the MBSS team will be linking changes in land use obtained from remote sensing data (MSS or AVHRR imagery) to stream monitoring results. Other potential sources of stressor trends will also be investigated, and the second round of the Survey will be designed to continue tracking changes in acid impacts related to implementation of controls under the 1990 Amendments of the Clean Air Act.

14.2 ENHANCED SAMPLE FRAME FOR ALL STREAMS

Even though the 1995-1997 MBSS sample frame was restricted to first- through third-order streams as described on 1:250,000-scale maps, many more small streams were assessed than in any other study of this magnitude. Partly because of this historical neglect of small streams and their susceptibility to degradation, it is important that the Survey monitor additional smaller streams. This can be accomplished by basing the second round of the Survey on a sample frame of streams as described on 1:100,000-scale maps.

At the same time, the Survey would be further enhanced by adding 4^{th}-order and larger streams to include all streams above tidal waters. To this end, the MBSS team has conducted methods comparisons in larger streams that can be implemented in the second round of the Survey. The MBSS team is also considering expanding the Survey to include tidal creeks. A pilot study has already been conducted by DNR (Hall et al.1999a) in order to assess the feasibility of assessing the biological condition of tidal streams in Maryland. A conversion model for sampling results using different protocols will be needed if integrated areawide estimates are to be calculated.

A third enhancement of the sample design for the second round of the Survey would involve designating additional strata for assessing distinct stream types, such as coldwater streams (<22 degrees C). Several researchers have noted that high-quality coldwater streams have fewer species and taxonomic groups than high-quality warmwater streams (Lyons et al. 1996). While such streams are naturally dominated by salmonids and cottids, environmental degradation often causes an increase in species richness (as a result of the invasion of more tolerant eurythermal and warmwater species), the opposite of what occurs in warmwater assemblages. The second round of the Survey should consider designating coldwater streams (and perhaps blackwater or other unusual stream types) for separate sampling or indicator development.

14.3 FINER GEOGRAPHIC SCALES

The needs to detect trends and to assess more stream types will be critical factors in the design of the second round of the Survey. In addition, natural resource managers and policymakers at DNR and elsewhere have an increasing need for assessment results at geographic scales finer than statewide and basinwide. Specifically, the Integrated Natural Resource Assessment and Unified Watershed Assessment are using 8-digit Maryland watersheds (138 in the state) for targeting, while specific protection and restoration projects may require using 12-digit watersheds (1166 in Maryland) or other methods to define the specific boundaries of the stream problem. This poses a difficult challenge because increasing sample density at finer scales substantially increases sampling effort. Therefore, DNR will be evaluating the new management questions to determine the best balance of fine-scale assessment, statewide coverage, and frequency of reporting (including the need to support 305b reporting to EPA).

Power analysis on the 1995-1997 MBSS results will be used to inform this design. One option under consideration is to decrease sample density for statewide estimates on an annual or other frequent basis, while supplementing this effort with more intense sampling in selected basins (and small watersheds) on a rotating basis over several years. The MBSS team is also considering using a simple random design (i.e., eliminating stratification by stream order) that would simplify calculating estimates and reporting results. It would also have the effect of increasing the proportion of sample sites on small streams (because streams would be sampled in proportion to their abundance).

14.4 BETTER STRESSOR CHARACTERIZATION

In addition to seeking finer resolution on the geographic boundaries of stream problems, natural resource managers are always searching for more information on potential stressors. The 1995-1997 MBSS made a conscious effort to balance the desire to collect as much stressor information as possible at each stream site with constraints on sampling time and analytical costs. Lessons from the first round of the Survey have identified ways of streamlining some data collection as well as candidates for additional stressor data collection. As initially conceived, substantial stressor identification will continue to be done using remote sensing and other data sets that can be linked to MBSS sample sites.

While the water chemistry parameters related to acidification have done a good job of elucidating this problem, collecting only nitrate-nitrogen has limited the utility of assessments of nutrient problems. The addition of phosphorus and other nitrogen compounds is being considered for the second round of the Survey. Adding analyses for fish tissue contaminants or pharmaceuticals (from animal feedlot discharges) is more problematic and costly. Dissolved oxygen will continue to be measured and ways to better assess results in light of diurnal and seasonal fluctuations are being considered. Perhaps most importantly, it has become apparent that continuous recordings of summer temperatures are important for identifying coldwater streams specifically and watershed disturbance in general. The MBSS team deployed temperature loggers in 5 of the 7 basins sampled in 1997 and plans to deploy temperature loggers at all future MBSS sites.

The quality of physical habitat in streams has long been recognized as an essential factor in the health of aquatic ecosystems. The 1995-1997 MBSS collected a large suite of qualitative and quantitative physical habitat parameters. It is important that effective measures of habitat quantity be built into the analyses of MBSS results. For the second round of the Survey, the MBSS team will consider consolidating some measures, but also adding parameters to better address (1) sedimentation effects, (2) differences between channelized and natural streams (i.e., levels of sinuosity, flow, large woody debris, and rootwads), (3) extent of artificially constrained floodplains, and (4) extent of migratory fish blockages.

The status of riparian vegetation also plays a critical role in maintaining stream integrity. In addition to the parameters collected in the 1995-1997 MBSS, the second round of the Survey may include tracking the loss of mature riparian vegetation (that provides greater stream and watershed benefits). Equally important is validating the utility of remote sensing information on riparian buffers with more accurate visual records. In particular, the Survey can provide one of the most effective means of understanding the extent and effect of piped discharges that bypass riparian vegetation.

It is also important to recognize that the biological indicators used in the Survey will continue to identify stream problems where the causes are not immediately apparent from associated stressor data. Finding new ways to identify causes of degradation (or of focusing additional monitoring that may) has implications for regulation of streams under the Clean Water Act (specifically, adding such sites to state 303d lists and ultimately preparing TMDLs for affected streams).

14.5 REFINED AND NEW INDICATORS

The use of rigorous, reference-based indicators has been a powerful means of assessing the condition of Maryland's streams and identifying likely causes of degradation. As described above, new ways of collecting or analyzing stressor information can lead to effective new indicators of human influence. One specific example is development of an indicator of impervious surface that can be derived from remote sensing land cover data. For the second round of the Survey, the MBSS team is considering developing the NDVI as an indicator for landscape stress. The MBSS team is also considering developing a combined ecological stress index (e.g., combining water chemistry, physical habitat, and landuse).

Although the fish IBI, benthic IBI, and physical habitat index have been validated and proven useful for assessing the results of the 1995-1997 MBSS, it is possible that these indicators could be improved with the identification of additional reference sites. The MBSS team is considering two efforts: (1) comparing MBSS reference sites with independently selected sites based on best professional judgement and (2) delineating the extent of current reference areas, possibly identifying better reference conditions near current sites.

The difference in results sometimes obtained between the fish IBI and benthic IBI emphasize the importance of assessing biological integrity with more than one organism group (as recommended by EPA 1990). Given that the fish IBI cannot be applied to streams draining watersheds smaller than 300 ha, and that more streams of this size will be included in the new 1:100,000-scale sample frame, a new biological indicator may be warranted. Currently the best candidate appears to be streamside salamanders, which can be quite abundance and diverse, especially in the western part of the state. The MBSS team is also considering combining the various biological indicators into a composite biological integrity index (e.g., the mean of the fish IBI, benthic IBI, and salamander IBI).

14.6 IMPROVED CHARACTERIZATION OF BIODIVERSITY

The MBSS team recognizes that, although the 1995-1997 MBSS was designed to focus on the overall condition of Maryland's streams, it includes information that can help characterize components of the state's biodiversity. Specifically, the number of total and rare fish species is known for each site and can be extended to larger regions. Significantly, the Survey provides an independent validation of the rarity of species and their appropriateness for listing as endangered, threatened, or of special concern by DNR.

At the same time, the 1995-1997 MBSS has limitations related to its random sampling design. It did not capture all of the rare species known from the state; nor did it recognize rare aquatic communities. Several options exist for enhancing the biodiversity information in the second round of the Survey. Time-series information can be used to determine trends in population abundances that may indicate species declines. Sampling may need to be focused in selected regions to provide accurate estimates of rare species. Such sampling may also identify sources of eggs for use in reintroducing declining species into areas from which they have been extirpated. The cluster analysis done on fish assemblages in minimally impaired streams could be expanded to create a classification of aquatic community types to be investigated for potential endangerment. Threats to rare species could be identified, especially the spread of exotics into streams previously supporting only native species. Lastly, MBSS information on the ecological condition of entire watersheds can be used to help designate biodiversity protection areas or to identify potential threats to known biodiversity hotspots.

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APPENDIX A

List of MBSS Management Questions

LIST OF MBSS MANAGEMENT QUESTIONS

A list of questions that potentially can be answered by the MBSS is given below. An asterisk indicates a question that is addressed in the 1995-1997 report (see Section 13.1).

A. Physical Characteristics

*1. How many wadeable stream miles of each stream order are in the study area?
*2. What is the geographic distribution of these streams?
*3. How many stream miles in the study area are remote?
*4. What % of streams in the study area are estimated to be ephemeral (i.e., dry at the time of summer sampling)?
*5. What % of stream miles are obstructed by beaver dams or other barriers?
*6. What % of stream miles are channelized with bank revetment or artificial banks?
*7. What % of stream miles have low bank stability?
*8. What % of stream miles have selected types of riparian buffers?
*9. What % of stream miles have selected widths of riparian buffers?
*10. What % of stream miles have little shading?
*11. What % of stream miles have high aesthetic quality?
12. What % of stream miles have selected types of instream habitat (e.g., riffles or pools)?
*13. What % of stream miles have low instream habitat quality (e.g., high embeddedness)?
*14. What % of stream miles in the study area are estimated to be publicly vs. privately owned?

*15. What is the geographic distribution of streams with these physical characteristics across the state?
*16. What % of stream miles have habitat conditions that differ from reference conditions as measured by indicators of stability (e.g., bank erosion) and diversity (e.g., substrate types)?
*17. What is the relationship between the degree of aesthetic quality and remoteness?

B. Water Chemistry

*18. What % of stream miles in the study area have low pH or ANC?
*19. What % of stream miles have high DOC, SO_4, or NO_3?
*20. What % of stream miles have DO less than the state water quality standard?
*21. What are the geographic distributions of streams with these water chemistry characteristics across the state?
*22. What are the average concentrations of these water chemistry parameters in the study area (NO_3 only)?
*23. How has the number of acidic and acid-sensitive streams (based on ANC) changed statewide since the 1987 Maryland Synoptic Stream Chemistry Survey (MSSCS)?

C. Biological Resources

*24. What % of stream miles in the study area have no fish, nongame fish, and gamefish species?
*25. What % of stream miles have exotic species?
*26. What % of stream miles have rare species?
*27. What is the geographic distribution of fish species across the state?
*28. What is the average density (number per stream mile) of individual fish species in the study area?
29. What is the biomass (kg per stream mile) of individual fish species in the study area?
30. What is the distribution of length classes for selected gamefish species?
*31. Which basins support the highest quality fisheries (i.e., have the greatest number of gamefish above minimum size in first to third order streams)?
*32. What % of stream miles in the study area have fish with abnormalities (pathologies and parasites)?
*33. What % of stream miles have fish with selected types of abnormalities?
34. How do fish species richness and fish community composition compare between put-and-take trout streams and unstocked streams in same basin?
*35. What % of stream miles have selected types of herpetofauna (e.g., frogs and toads, salamanders, and reptiles)?
*36. What is the geographic distribution of reptiles and amphibians across the state?
37. What is the average density (number per stream mile) of reptiles and amphibians in the study area?
*38. Where are additional populations of rare fish and herpetofauna not previously documented located?
*39. To what degree do the flowing, nontidal waters of the state have balanced indigenous populations of biota as measured by the fish community (e.g., What is the % of stream miles in degraded condition based on the fish Index of Biotic Integrity)
*40. To what degree do the flowing, nontidal waters of the state have balanced indigenous populations of biota as measured by the benthic macroinvertebrate community (e.g., What is the % of stream miles in degraded condition based on EPT taxa, Hilsenhoff Biotic Index, or benthic Index of Biotic Integrity)?

D. Landscape Characteristics

*41. What % of area (acres) in the study area is in the following land use categories: agriculture, forest, urban, and wetlands?
*42. What is the geographic distribution of the area of these land use categories in the study area?
43. What % of stream miles have Superfund sites in the study area?
44. What % of stream miles have point sources?
45. What % of stream miles receive storm water discharge?
46. What % of watersheds in the study area have had pesticide or nutrient applications?
47. What % of watersheds that have been sprayed continue to have gypsy moth infestations?

*48. Where are the minimally affected streams and what are their land use/landscape characteristics?
49. What are the landscape connectivity indices (shape, complexity, and dominance of patch types) for watersheds in the study area?
50. How have the answers to the above questions (landscape characteristics) changed between 1970 and 1990?

E. Resource-stressor Associations

*51. What % of chronically acidic stream miles in the study area are associated with acid mine drainage (AMD) or acidic deposition as measured by pH, ANC, and SO_4?
*52. What is the relationship (subpopulation analysis or correlation) between water chemistry (ANC, pH, DOC, SO_4, NO_3, and DO) and abundance of fish species? [pH and ANC only]
*53. What is the relationship between stream channelization and the abundance of fish species?
54. What is the relationship between stream bank stability and the abundance of fish species?
*55. What is the relationship between riparian buffer and the abundance of fish species?
*56. What is the relationship between remoteness and abundance of fish species?
57. What % of stream miles in the study area with degraded biotic integrity are associated with AMD, acidic deposition, eutrophication, habitat degradation, and the presence of exotics?
*58. What % of stream miles in the study area have suitable physical habitat and would be expected to have desired species (e.g., gamefish or endangered species) if water chemistry or other stressors were absent (i.e., are candidates for restoration)?

F. Resource-landscape associations

*59. What is the relationship between land use and stream resources using indices of the biological community such as the IBI?
60. What % of stream miles in the study area with degraded biotic integrity are associated with selected land uses and land management practices?
61. What % of stream miles in the study area with degraded biotic integrity are associated with landscape indices such as connectivity, shape complexity, and dominance of patches?
62. Are changes in the % of stream miles in the study area with degraded biotic integrity associated with changes in landscape indices over the period of 1970 to 1990?
63. How does the quality of biota (as measured by the IBI) compare among geographic areas with selected growth strategies?
64. Which basins should receive priority for restoration or enhancement of fishability and nongame benefits based on future land use?

APPENDIX B

Number of Stream Miles and Number of Sites Sampled

Table B-1. Number of stream miles by stream order for basins sampled in the Maryland Biological Stream Survey, 1995-1997

Basin	Order 1	Order 2	Order 3	Combined
Youghiogheny	244.0	87.2	43.1	374.3
North Branch Potomac	386.9	130.0	77.3	594.2
Upper Potomac	463.9	161.9	42.8	668.6
Middle Potomac	742.0	230.5	129.9	1102.4
Potomac Washington Metro	491.4	119.6	78.2	689.2
Lower Potomac	502.6	100.0	48.4	651.0
Patuxent	698.1	157.4	53.2	908.7
West Chesapeake	180.3	29.1	10.8	220.2
Patapsco	422.6	134.1	60.0	616.7
Gunpowder	348.5	74.8	42.8	466.1
Bush	131.0	31.3	23.8	186.1
Susquehanna	208.2	42.3	24.7	275.2
Elk	162.9	37.5	11.3	211.7
Chester	216.6	64.2	10.3	291.1
Choptank	208.7	32.1	16.1	256.9
Nanticoke/Wicomico	192.8	28.7	5.5	227.0
Pocomoke	219.4	38.0	13.6	271.0
TOTAL	5819.9	1498.7	691.8	8010.4

Table B-2. Number of stream sites sampled by stream order and basin for the 1995-1997 MBSS

Basin	**Order 1**		**Order 2**		**Order 3**		**Combined**	
	Spring	**Summer**	**Spring**	**Summer**	**Spring**	**Summer**	**Spring**	**Summer**
Youghiogheny 1995	13	11	14	13	14	14	41	38
Youghiogheny 1997	12	11	17	17	15	14	44	42
North Branch Potomac	17	14	22	20	23	23	62	57
Upper Potomac	23	19	31	31	15	15	69	65
Middle Potomac	29	29	39	37	41	41	109	107
Potomac Washington Metro	23	22	22	22	26	26	71	70
Lower Potomac	20	19	19	16	15	15	54	50
Patuxent	35	35	29	28	18	17	82	80
West Chesapeake	11	10	12	10	12	12	35	32
Patapsco 1995	18	18	23	23	20	20	61	61
Patapsco 1996	21	21	25	25	22	19	68	65
Gunpowder	18	18	13	13	14	14	45	45
Bush	6	6	6	5	8	8	20	19
Susquehanna	13	12	12	12	12	11	37	35
Elk	7	7	7	7	4	4	18	18
Chester	15	13	12	12	15	14	42	39
Choptank 1996	10	7	6	6	5	5	21	18
Choptank 1997	11	8	8	5	6	6	25	19
Nanticoke/Wicomico	11	11	6	6	0	0	17	17
Pocomoke	12	9	10	7	12	12	34	28
TOTAL	325	300	333	315	297	290	955	905

APPENDIX C

Lists of Common and Scientific Names for all Taxa

Table C-1. Fish species recorded in the 1995-1997 MBSS random sampling*	
Common Name	**Scientific Name**
Lampreys: Petromyzontidae	
American brook lamprey	*Lampetra appendix*
Least brook lamprey	*Lampetra aepyptera*
Sea lamprey	*Petromyzon marinus*
Gars: Lepisosteidae	
Longnose gar	*Lepisosteus osseus*
Freshwater Eels: Anguillidae	
American eel	*Anguilla rostrata*
Herrings: Clupeidae	
Gizzard Shad	*Dorosoma cepedianum*
Pikes: Esocidae	
Chain pickerel	*Esox niger*
Redfin pickerel	*Esox americanus*
Mudminnows: Umbridae	
Eastern mudminnow	*Umbra pygmaea*
Minnows: Cyprinidae	
Blacknose dace	*Rhinichthys atratulus*
Bluntnose minnow	*Pimephales notatus*
Central Stoneroller	*Campostoma anomalum*
Comely shiner	*Notropis amoenas*
Common carp	*Cyprinus carpio*
Common shiner	*Luxillus cornutus*
Creek chub	*Semotilus atromaculatus*
Cutlips minnow	*Exoglossum maxillingua*
Eastern slivery minnow	*Hypognatus regius*
Fallfish	*Semotilus corporalis*
Fathead minnow	*Pimephales promelas*
Golden shiner	*Notemigonus crysoleucas*
Goldfish	*Carassius auratus*
Ironcolor shiner	*Notropis chalybaeus*
Longnose dace	*Rhinichthys cataractae*
Pearl dace	*Margariscus margarita*
River chub	*Nocomis micropogon*
Rosyface shiner	*Notropis rubellus*
Rosyside dace	*Clinostomus funduloides*
Satinfin shiner	*Cyprinella analostona*

Table C-1. Cont'd	
Common Name	**Scientific Name**
Silverjaw minnow	*Notropis buccatus*
Spotfin shiner	*Cyprinella spiloptera*
Spottail shiner	*Notropis hudsonius*
Striped shiner	*Luxilus chrysocephalus*
Swallowtail shiner	*Notropis procne*
Cyprinid hybrid	
Suckers: Catostomidae	
Creek chubsucker	*Erimyzon oblongus*
Golden redhorse	*Moxostoma erythrurum*
Northern hogsucker	*Hypentelium nigricans*
Shorthead redhorse	*Moxostoma macrolepidotum*
White sucker	*Catostomus commersoni*
Catfishes: Ictaluridae	
Brown bullhead	*Ameiurus nebulosus*
Channel catfish	*Ictalurus punctatus*
Margined madtom	*Noturus insignis*
Tadpole madtom	*Noturus gyrinus*
White catfish	*Ameiurus catus*
Yellow bullhead	*Ameiurus natalis*
Trouts: Salmonidae	
Brook trout	*Salvelinus fontinalis*
Brown trout	*Salmo trutta*
Cutthroat trout	*Oncorhynchus clarki*
Rainbow trout	*Oncorhynchus mykiss*
Pirate Perches: Aphredoderidae	
Pirate perch	*Aphredoderus sayanus*
Killifishes: Fundulidae	
Banded killifish	*Fundulus diaphanus*
Mummichog	*Fundulus heteroclitus*
Livebearers: Poeciliidae	
Mosquitofish	*Gambusia holbrooki*
Sculpins: Cottidae	
Checkered sculpin	*Cottus* sp. n.
Mottled sculpin	*Cottus bairdi*
Potomac sculpin	*Cottus girardi*

Table C-1. Cont'd	
Common Name	**Scientific Name**
Striped Basses: Moronidae	
Striped bass	*Morone saxatilis*
White perch	*Morone americana*
Sunfishes: Centrarchidae	
Banded sunfish	*Enneacanthus obesus*
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Bluespotted sunfish	*Enneacanthus gloriosus*
Flier	*Centrarchus macropterus*
Green sunfish	*Lepomis cyanellus*
Largemouth bass	*Micropterus salmoides*
Longear sunfish	*Lepomis megalotis*
Mud sunfish	*Acantharchus pomotis*
Pumpkinseed	*Lepomis gibbosus*
Redbreast sunfish	*Lepomis auritus*
Rock bass	*Ambloplites rupestris*
Warmouth	*Lepomis gulosus*
Smallmouth bass	*Micropterus dolomieu*
Lepomis hybrid	
Perches: Percidae	
Fantail darter	*Etheostoma flabellare*
Glassy darter	*Etheostoma vitreum*
Greenside darter	*Etheostoma blennioides*
Johnny darter	*Etheostoma nigrum*
Logperch	*Percina caprodes*
Rainbow darter	*Etheostoma caeruleum*
Shield darter	*Percina peltata*
Stripeback darter	*Percina notogramma*
Swamp darter	*Etheostoma fusiforme*
Tessellated darter	*Etheostoma olmstedi*
Yellow perch	*Perca flavescens*

* In addition to fish collected during MBSS sampling, two additional species were captured at supplemental, non-randomly selected sampling sites: Atlantic menhaden (*Brevoortia tyrannus*) and banded darter (*Etheostoma zonale*).

Table C-2. Freshwater fish species (game and nongame) known to be found in Maryland (Lee et al. 1981), but not recorded in the 1995-97 MBSS

Common Name	Scientific Name
Cyprinidae	
Bridle shiner	*Notropis bifrenatus*
Cheat minnow	*Rhinichthys bowersi*
Emerald shiner	*Notropis atherinoides*
Grass carp	*Ctenopharyngodon idella*
Redside dace	*Clinostomus elongatus*
Silver shiner	*Notropis photogenis*
Tench	*Tinca tinca*
Catostomidae	
Black redhorse	*Moxostoma duquesnei*
Longnose sucker	*Catostomus catostomus*
Quillback	*Carpiodes cyprinus*
Ictaluridae	
Stonecat	*Noturus flavus*
Cottidae	
Slimy sculpin	*Cottus cognatus*
Centrarchidae	
Blackbanded sunfish	*Enneacanthus chaetodon*
Redear sunfish	*Lepomis microlophus*
Percidae	
Blackside darter	*Percina maculata*
Maryland darter	*Etheostoma sellare*
Variegate darter	*Etheostoma variatum*

Table C-3. List of benthic taxa recorded in the 1995-97 MBSS							
Class	**Order**	**Family**	**Subfamily**	**Tribe**	**Genus**	**Final ID**	**Note**
Nematomorpha						Nematomorpha	1
Enopla	Hoplonemertea	Tetrastemmatidae					
					Prostoma	Prostoma	
Turbellaria							
	Tricladida	Planariidae					
					Cura	Cura	
					Dugesia	Dugesia	
Oligochaeta							
	Lumbriculida	Lumbriculidae				Lumbriculidae	
	Tubificida	Enchytraeidae				Enchytraeidae	2
		Naididae				Naididae	2
		Tubificidae					2
					Limnodrilus	Limnodrilus	
					Spirosperma	Spirosperma	
Hirudinea							
	Pharyngobdellida	Erpobdellidae					
					Mooreobdella	Mooreobdella	
	Rhynchobdellida	Glossiphoniidae					
					Helobdella	Helobdella	
		Piscicolidae			Piscicola	Piscicola	
Gastropoda	Basommatophora	Ancylidae					
					Ferrissia	Ferrissia	
		Lymnaeidae					
					Fossaria	Fossaria	
					Pseudosuccinea	Pseudosuccinea	
					Radix	Radix	
					Stagnicola	Stagnicola	
		Physidae					
					Physella	Physella	
		Planorbidae					
					Gyraulus	Gyraulus	
					Helisoma	Helisoma	
					Menetus	Menetus	
					Planorbella	Planorbella	
					Promenetus	Promenetus	
	Mesogastropoda	Bithyniidae			Bithynia	Bithynia	
		Hydrobiidae					
					Amnicola	Amnicola	
					Hydrobia	Hydrobia	
		Pleuroceridae			Goniobasis	Goniobasis	
					Leptoxis	Leptoxis	
		Valvatidae			Valvata	Valvata	
		Viviparidae			Campeloma	Campeloma	
					Viviparus	Viviparus	

Table C-3. Cont'd

Class	Order	Family	Subfamily	Tribe	Genus	Final ID	Note
Pelecypoda	Unionoida	Unionidae				Unionidae	3
	Veneroida	Corbiculidae			Corbicula		
		Sphaeriidae					
					Pisidium	Pisidium	
					Sphaerium	Sphaerium	
Malacostraca	Amphipoda						
		Crangonyctidae					
					Crangonyx	Crangonyx	
		Gammaridae			Gammarus	Gammarus	
					Stygonectes	Stygonectes	
		Hyalellidae			Hyalella	Hyalella	
	Copepoda					Copepoda	
	Decapoda	Cambaridae					
					Cambarus	Cambarus	
					Orconectes	Orconectes	
		Palaemonidae			Palaemonetes	Palaemonetes	
	Isopoda						
		Asellidae			Caecidotea	Caecidotea	
	Ostracoda					Ostracoda	
					Lirceus	Lirceus	
Insecta	Collembola						
		Isotomidae			Isotomurus	Isotomurus	
	Ephemeroptera						
		Ameletidae					
					Ameletus	Ameletus	
		Baetidae					
					Acentrella	Acentrella	
					Acerpenna	Acerpenna	
					Baetis	Baetis	
					Barbaetis	Barbaetis	
					Callibaetis	Callibaetis	
					Centroptilum	Centroptilum	
					Diphetor	Diphetor	
					Procloeon	Procloeon	
		Baetiscidae			Baetisca	Baetisca	
		Caenidae			Caenis	Caenis	
		Ephemerellidae					
					Drunella	Drunella	
					Ephemerella	Ephemerella	
					Eurylophella	Eurylophella	
					Serratella	Serratella	
					Timpanoga	Timpanoga	
		Ephemeridae			Ephemera	Ephemera	
					Hexagenia	Hexagenia	

Table C-3. Cont'd							
Class	**Order**	**Family**	**Subfamily**	**Tribe**	**Genus**	**Final ID**	**Note**
		Heptageniidae					
					Cinygmula	Cinygmula	
					Epeorus	Epeorus	
					Heptagenia	Heptagenia	
					Leucrocuta	Leucrocuta	
					Nixe	Nixe	
					Stenacron	Stenacron	
					Stenonema	Stenonema	
		Isonychiidae			Isonychia	Isonychia	
		Leptophlebiidae					
					Habrophlebia	Habrophlebia	
					Leptophlebia	Leptophlebia	
					Paraleptophlebia	Paraleptophlebia	
		Metretopodidae			Siphloplectron	Siphloplectron	
		Potamanthidae			Anthopotamus	Anthopotamus	
		Siphlonuridae					
					Siphlonurus	Siphlonurus	
	Odonata						
		Aeshnidae					
					Basiaeschna	Basiaeschna	
					Boyeria	Boyeria	
		Calopterygidae			Calopteryx	Calopteryx	
		Coenagrionidae					
					Argia	Argia	
					Enallagma	Enallagma	
					Ischnura	Ischnura	
					Nehalennia	Nehalennia	
		Cordulegastridae			Cordulegaster	Cordulegaster	
		Corduliidae					
					Macromia	Macromia	
					Somatochlora	Somatochlora	
		Gomphidae					
					Arigomphus	Arigomphus	
					Dromogomphus	Dromogomphus	
					Erpetogomphus	Erpetogomphus	
					Gomphus	Gomphus	
					Hagenius	Hagenius	
					Lanthus	Lanthus	
					Progomphus	Progomphus	
					Stylogomphus	Stylogomphus	
		Libellulidae					
					Leucorrhinia	Leucorrhinia	
					Libellula	Libellula	

Table C-3. Cont'd							
Class	**Order**	**Family**	**Subfamily**	**Tribe**	**Genus**	**Final ID**	**Note**
	Plecoptera	Capniidae					
					Allocapnia	Allocapnia	
					Capnia	Capnia	
					Paracapnia	Paracapnia	
		Chloroperlidae					
					Alloperla	Alloperla	
					Haploperla	Haploperla	
					Perlinella	Perlinella	
					Sweltsa	Sweltsa	
		Leuctridae					
					Leuctra	Leuctra	
					Paraleuctra	Paraleuctra	
		Nemouridae					
					Amphinemura	Amphinemura	
					Nemoura	Nemoura	
					Ostrocerca	Ostrocerca	
					Prostoia	Prostoia	
					Shipsa	Shipsa	
					Soyedina	Soyedina	
		Peltoperlidae					
					Peltoperla	Peltoperla	
					Tallaperla	Tallaperla	
		Perlidae					
					Acroneuria	Acroneuria	
					Eccoptura	Eccoptura	
					Neoperla	Neoperla	
					Paragnetina	Paragnetina	
					Perlesta	Perlesta	4
					Phasganophora	Phasganophora	5
		Perlodidae					
					Clioperla	Clioperla	
					Cultus	Cultus	
					Diploperla	Diploperla	
					Isoperla	Isoperla	
					Malirekus	Malirekus	
		Pteronarcyidae			Pteronarcys	Pteronarcys	
		Taeniopterygidae					
					Oemopteryx	Oemopteryx	
					Strophopteryx	Strophopteryx	
					Taeniopteryx	Taeniopteryx	
	Hemiptera	Belostomatidae			Belostoma	Belostoma	6
		Corixidae					
					Palmacorixa	Palmacorixa	
					Trichocorixa	Trichocorixa	

Table C-3. Cont'd

Class	Order	Family	Subfamily	Tribe	Genus	Final ID	Note
		Gerridae			Gerris	Gerris	
					Trepobates	Trepobates	
		Notonectidae			Notonecta	Notonecta	
		Veliidae			Microvelia	Microvelia	
	Megaloptera	Corydalidae			Chauliodes	Chauliodes	
					Corydalus	Corydalus	
					Nigronia	Nigronia	
		Sialidae					
					Sialis	Sialis	
	Neuroptera	Sisyridae			Climacia	Climacia	7
	Trichoptera						
		Brachycentridae					
					Brachycentrus	Brachycentrus	
					Micrasema	Micrasema	
		Calamoceratidae			Heteroplectron	Heteroplectron	
		Dipseudopsidae			Phylocentropus	Phylocentropus	8
		Glossosomatidae					
					Agapetus	Agapetus	
					Glossosoma	Glossosoma	
		Hydropsychidae					
					Cheumatopsyche	Cheumatopsyche	
					Diplectrona	Diplectrona	
					Homoplectra	Homoplectra	
					Hydropsyche	Hydropsyche	
					Parapsyche	Parapsyche	
		Hydroptilidae					
					Hydroptila	Hydroptila	
					Leucotrichia	Leucotrichia	
					Ochrotrichia	Ochrotrichia	
					Oxyethira	Oxyethira	
		Lepidostomatidae			Lepidostoma	Lepidostoma	
		Leptoceridae					
					Ceraclea	Ceraclea	
					Mystacides	Mystacides	
					Nectopsyche	Nectopsyche	
					Oecetis	Oecetis	
					Triaenodes	Triaenodes	
		Limnephilidae					
					Goera	Goera	
					Hydatophylax	Hydatophylax	
					Ironoquia	Ironoquia	
					Limnephilus	Limnephilus	
					Platycentropus	Platycentropus	
					Pycnopsyche	Pycnopsyche	

Table C-3. Cont'd							
Class	**Order**	**Family**	**Subfamily**	**Tribe**	**Genus**	**Final ID**	**Note**
		Odontoceridae			Psilotreta	Psilotreta	
		Philopotamidae					
					Chimarra	Chimarra	
					Dolophilodes	Dolophilodes	
					Wormaldia	Wormaldia	
		Phryganeidae			Ptilostomis	Ptilostomis	
		Polycentropodidae					
					Neureclipsis	Neureclipsis	
					Nyctiophylax	Nyctiophylax	
					Polycentropus	Polycentropus	
		Psychomyiidae			Lype	Lype	
					Psychomyia	Psychomyia	
		Rhyacophilidae			Rhyacophila	Rhyacophila	
		Uenoidae					
					Neophylax	Neophylax	9
	Lepidoptera						
		Pyralidae				Pyralidae	
		Tortricidae				Tortricidae	
	Coleoptera	Curculionidae				Curculionidae	
		Dryopidae			Helichus	Helichus	
		Dytiscidae					
					Agabus	Agabus	
					Cybister	Cybister	
					Deronectes	Deronectes	
					Derovatellus	Derovatellus	
					Hydroporus	Hydroporus	
		Elmidae					
					Ancyronyx	Ancyronyx	
					Dubiraphia	Dubiraphia	
					Macronychus	Macronychus	
					Optioservus	Optioservus	
					Oulimnius	Oulimnius	
					Promoresia	Promoresia	
					Stenelmis	Stenelmis	
		Gyrinidae			Dineutus	Dineutus	
					Gyrinus	Gyrinus	
		Haliplidae			Haliplus	Haliplus	
					Peltodytes	Peltodytes	
		Hydrophilidae			Berosus	Berosus	
					Enochrus	Enochrus	
					Hydrobius	Hydrobius	
					Hydrochus	Hydrochus	
					Hydrophilus	Hydrophilus	
					Sperchopsis	Sperchopsis	

Table C-3. Cont'd

Class	Order	Family	Subfamily	Tribe	Genus	Final ID	Note
					Tropisternus	Tropisternus	
		Psephenidae			Ectopria	Ectopria	
					Psephenus	Psephenus	
		Ptilodactylidae			Anchytarsus	Anchytarsus	
		Scirtidae					
					Cyphon		
	Diptera						
		Athericidae			Atherix	Atherix	
		Blephariceridae			Blepharicera	Blepharicera	
		Ceratopogonidae					
					Alluaudomyia	Alluaudomyia	
					Bezzia	Bezzia	
					Ceratopogon	Ceratopogon	
					Culicoides	Culicoides	
					Helius	Helius	
					Mallochohelea	Mallochohelea	
					Probezzia	Probezzia	
					Sphaeromias	Sphaeromias	
		Chaoboridae			Chaoborus	Chaoborus	
		Chironomidae					
			Chironimae			Chironimae	Chir
					Chironimini	Chironimni	Chir
					Chironomus	Chironomus	Chir
					Cladopelma	Cladopelma	Chir
					Cryptochironomus	Cryptochironomus	Chir
					Cryptotendipes	Cryptotendipes	Chir
					Cryptochironomus	Cryptochironomus	Chir
					Cryptotendipes	Cryptotendipes	Chir
					Dicrotendipes	Dicrotendipes	Chir
					Endochironomus	Endochironomus	Chir
					Glyptotendipes	Glyptotendipes	Chir
					Kiefferulus	Kiefferulus	Chir
					Microtendipes	Microtendipes	Chir
					Omisus	Omisus	Chir
					Parachironomus	Parachironomus	Chir
					Paracladopelma	Paracladopelma	Chir
					Paralauterborniella	Paralauterborniella	Chir
					Paratendipes	Paratendipes	Chir
					Saetheria	Saetheria	Chir
					Stenochironomus	Stenochironomus	Chir
					Stictochironomus	Stictochironomus	Chir
					Phaenopsectra	Phaenopsectra	Chir
					Polypedilum	Polypedilum	Chir
					Tribelos	Tribelos	Chir

Table C-3. Cont'd

Class	Order	Family	Subfamily	Tribe	Genus	Final ID	Note
				Tanytarsini		Tanytarsini	Tant
					Cladotanytarsus	Cladotanytarsus	Tant
					Micropsectra	Micropsectra	Tant
					Paratanytarsus	Paratanytarsus	Tant
					Rheotanytarsus	Rheotanytarsus	Tant
					Stempellinella	Stempellinella	Tant
					Sublettea	Sublettea	Tant
					Tanytarsus	Tanytarsus	Tant
					Zavrelia	Zavrelia	Tant
			Diamesinae			Diamesinae	Diam
					Diamesa	Diamesa	Diam
					Pagastia	Pagastia	Diam
					Potthastia	Potthastia	Diam
					Sympotthastia	Sympotthastia	Diam
					Syndiamesa	Syndiamesa	Diam
			Orthocladiinae			Orthocladiinae	Orth
					Brillia	Brillia	Orth
					Cardiocladius	Cardiocladius	Orth
					Chaetocladius	Chaetocladius	Orth
					Corynoneura	Corynoneura	Orth
					Cricotopus	Cricotopus	Orth
					Cricotopus/Orthocladius	Cricotopus/Orthocladius	Orth
					Diplocladius	Diplocladius	Orth
					Eukiefferiella	Eukiefferiella	Orth
					Heleniella	Heleniella	Orth
					Heterotrissocladius	Heterotrissocladius	Orth
					Hydrobaenus	Hydrobaenus	Orth
					Limnophyes	Limnophyes	Orth
					Lopescladius	Lopescladius	Orth
					Nanocladius	Nanocladius	Orth
					Orthocladius	Orthocladius	Orth
					Orthocladiinae A	Orthocladiinae A	Orth
					Orthocladiinae B	Orthocladiinae B	Orth
					Parachaetocladius	Parachaetocladius	Orth
					Parakiefferiella	Parakiefferiella	Orth
					Parametriocnemus	Parametriocnemus	Orth
					Paraphaenocladius	Paraphaenocladius	Orth
					Paratrichocladius	Paratrichocladius	Orth
					Psectrocladius	Psectrocladius	Orth
					Pseudorthocladius	Pseudorthocladius	Orth
					Psilometriocnemus	Psilometriocnemus	Orth
					Rheocricotopus	Rheocricotopus	Orth
					Symposiocladius	Symposiocladius	Orth

Table C-3. Cont'd

Class	Order	Family	Subfamily	Tribe	Genus	Final ID	Note
					Rheosmittia	Rheosmittia	Orth
					Thienemanniella	Thienemanniella	Orth
					Tvetenia	Tvetenia	Orth
					Unniella	Unniella	Orth
					Xylotopus	Xylotopus	Orth
			Prodiamesinae		Odontomesa	Odontomesa	Prod
					Prodiamesa	Prodiamesa	Prod
			Tanypodinae			Tanypodinae	
					Ablabesmyia	Ablabesmyia	Tanp
					Apsectrotanypus	Apsectrotanypus	Tanp
					Clinotanypus	Clinotanypus	Tanp
					Conchapelopia	Conchapelopia	Tanp
					Krenopelopia	Krenopelopia	Tanp
					Labrundinia	Labrundinia	Tanp
					Larsia	Larsia	Tanp
					Macropelopia	Macropelopia	Tanp
					Meropelopia	Meropelopia	Tanp
					Natarsia	Natarsia	Tanp
					Nilotanypus	Nilotanypus	Tanp
					Paramerina	Paramerina	Tanp
					Pentaneura	Pentaneura	Tanp
					Procladius	Procladius	Tanp
					Rheopelopia	Rheopelopia	Tanp
					Tanypus	Tanypus	Tanp
					Thienemannimyia	Thienemannimyia	Tanp
					Trissopelopia	Trissopelopia	Tanp
					Zavrelimyia	Zavrelimyia	Tanp
		Culicidae			Aedes	Aedes	
		Dixidae			Dixa	Dixa	
		Dolichopodidae					
		Empididae					
					Chelifera	Chelifera	
					Clinocera	Clinocera	
					Hemerodromia	Hemerodromia	
		Ephydridae					
		Muscidae					
					Limnophora	Limnophora	
		Psychodidae			Pericoma	Pericoma	
		Ptychopteridae			Bittacomorpha	Bittacomorpha	
		Simuliidae					
					Cnephia	Cnephia	
					Prosimulium	Prosimulium	
					Simulium	Simulium	
					Stegopterna	Stegopterna	

Table C-3. Cont'd

Class	Order	Family	Subfamily	Tribe	Genus	Final ID	Note
		Stratiomyidae			Stratiomys	Stratiomys	
		Tabanidae					
					Chrysops	Chrysops	
					Tabanus	Tabanus	
		Tipulidae					
					Antocha	Antocha	
					Cryptolabis	Cryptolabis	
					Dicranota	Dicranota	
					Erioptera	Erioptera	
					Hexatoma	Hexatoma	
					Limnophila	Limnophila	
					Limonia	Limonia	
					Molophilus	Molophilus	
					Ormosia	Ormosia	
					Pilaria	Pilaria	
					Pseudolimnophila	Pseudolimnophila	
					Tipula	Tipula	

1. Nematomorpha is a phylum level identification. No class level identification was made.
2. Brinkhurst (1986). ITIS (1998) places the family in the order Haplotaxida.
3. Margulis and Schwartz (1988). ITIS (1998) uses the class name Bivalvia.
4. Merritt and Cummins (1996). ITIS (1998) places *Perlesta* in the family Chloroperlidae.
5. Merritt and Cummins (1996). ITIS (1998) uses the genus name *Agnetina*.
6. Merritt and Cummins (1996). ITIS (1998) uses the order name Heteroptera.
7. Merritt and Cummins (1996). ITIS (1998) places Sisyridae in the order Megaloptera.
8. Merritt and Cummins (1996). ITIS (1998) places *Phylocentropus* in the family Psychomyiidae.
9. Merritt and Cummins (1996). ITIS (1998) places *Neophylax* in the family Limnephilidae.

Tanp Subfamily Tanypodinae
Orth Subfamily Orthocladiinae
Chir Tribe Chironominae
Tant Tribe Tanytarsini
Diam Subfamily Diamesinae
Prod Subfamily Prodiamesinae

Table C-4. Amphibians and reptiles recorded in the 1995-1997 MBSS	
Common Name	**Scientific Name**
Ambystomatidae	
Jefferson salamander	*Ambystoma jeffersonianum*
Marbled salamander	*Ambystoma opacum*
Salamandridae	
Red spotted newt	*Notopthalmus v. viridescens*
Plethodontidae	
Eastern mud salamander	*Pseudotriton montanus*
Longtail salamander	*Eurycea l. longicauda*
Mountain dusky salamander	*Desmognathus ochrophaeus*
Northern dusky salamander	*Desmognathus f. fuscus*
Northern two-lined salamander	*Eurycea bislineata*
Northern slimy salamander	*Plethodon glutinosus*
Northern spring salamander	*Gyrinophilus p. porphyriticus*
Red salamander	*Pseudotriton ruber*
Redback salamander	*Plethodon cinereus*
Seal salamander	*Desmognathus monticola*
Phrynosomatidae	
Northern fence lizard	*Sceloporus undulatus hyacinthinus*
Bufonidae	
American toad	*Bufo americanus*
Fowler's toad	*Bufo woodhousii fowleri*
Hylidae	
Gray treefrog	*Hyla versicolor/chrysocelis*
Northern cricket frog	*Acris crepitans*
Northen spring peeper	*Pseudacris c. crucifer*
Ranidae	
Bullfrog	*Rana catesbeiana*
Green frog	*Rana clamitans melanota*
Northern leopard frog	*Rana pipiens*
Pickerel frog	*Rana palaustris*
Southern leopard frog	*Rana utricularia*
Wood frog	*Rana sylvatica*

Table C-4. Cont'd	
Common Name	**Scientific Name**
Chelydridae	
Common snapping turtle	*Chelydra serpentina*
Kinosternidae	
Common musk turtle	*Sternotherus odoratus*
Eastern mud turtle	*Kinosternon s. subrubrum*
Emydidae	
Eastern box turtle	*Terrapene c. carolina*
Eastern painted turtle	*Chrysemys p. picta*
Redbelly turtle	*Pseudemys rubriventris*
Spotted turtle	*Clemmys guttata*
Wood turtle	*Clemmys insculpta*
Scincidae	
Five-lined skink	*Eumeces fasciatus*
Colubridae	
Black rat snake	*Elaphe o. obsoleta*
Eastern garter snake	*Thamnophis s. sirtalis*
Eastern smooth earth snake	*Virginia valeriae*
Eastern worm snake	*Carphophis amoenus*
Northern black racer	*Coluber c. constrictor*
Northern ringneck snake	*Diadophis punctatus edwardsii*
Northern water snake	*Nerodia s. sipedon*
Queen snake	*Regina septemvittata*
Rough green snake	*Opheodrys aestivus*
Smooth green snake	*Opheodrys vernalis*
Viperidae	
Northern copperhead	*Agkistrodon contortix mokasen*

Table C-5. Amphibians and reptiles known to be found in Maryland (Harris 1975), but not recorded in the 1995-97 MBSS	
Common Name	**Scientific Name**
Cryptobranchidae	
Hellbender	*Cryptobranchus alleganiensis*
Necturidae	
Mudpuppy	*Nectarus maculosus*
Sirenidae	
Greater siren	*Siren lacertina*
Ambystomatidae	
Eastern tiger salamander	*Ambystoma t. tigrinum*
Spotted salamander	*Ambystoma maculatum*
Plethodontidae	
Four-toed salamander	*Hemidactylium scutatum*
Green salamander	*Aneides aeneus*
Wehrle's salamander	*Plethodon wehrlei*
Valley & Ridge salamander	*Plethodon hoffmani*
Pelobatidae	
Eastern spadefoot	*Scaphiopus h. holbrooki*
Microhylidae	
Eastern narrow mouth toad	*Gastrophryne carolinensis*
Hylidae	
Barking treefrog	*Hyla gratiosa*
Green treefrog	*Hyla cinerea*
Mountain chorus frog	*Pseudacris brachyphona*
New Jersey chorus frog	*Pseudacris kalmi*
Upland chorus frog	*Pseudacris feriarum*
Ranidae	
Carpenter frog	*Rana virgatipes*
Emydidae	
Bog turtle	*Clemmys muhlenbergi*
Eastern river cooter	*Pseudemys c. conicinna*
Northen diamondback terrapin	*Malaclemys t. terrapin*
Common map turtle	*Graptemys geographica*
Midland painted turtle	*Chrysemys p. marginata*
Red-eared slider	*Trachemys c. elegans*

Table C-5. Cont'd	
Common Name	**Scientific Name**
Teiidae	
Six-lined racerunner	*Cnemidophorus s. sexlineatus*
Scincidae	
Broad head skink	*Eumeces laticeps*
Ground skink	*Scincella lateralis*
Northern coal skink	*Eumeces anthracinus*
Southeastern five-lined skink	*Eumeces inexpectatus*
Colubridae	
Rainbow snake	*Farancia erytrogramma*
Eastern hognose snake	*Heterodon platirhinos*
Corn snake	*Elaphe g. guttata*
Northern pine snake	*Pituophis m. melanoleucus*
Eastern kingsnake	*Lampropeltis getulus*
Mole snake	*Lampropeltis calligaster rhombomaculata*
Eastern milk snake	*Lampropeltis t. triangulum*
Northern scarlet snake	*Cemophora c. copei*
Redbelly water snake	*Natrix e. erythrogaster*
Northern brown snake	*Storeria d. dekayi*
Northern redbelly snake	*Storeria occipitomaculata*
Mountain earth snake	*Virginia p. pulchea*
Eastern ribbon snake	*Thamophilis s. sauritus*
Viperidae	
Timber rattlesnake	*Crotalus horridus*
Trionychidae	
Eastern spiny softshell	*Apalone s. spinifera*

Table C-6. Mussels recorded in the 1995-1997 MBSS	
Common Name	Scientific Name
Unionidae	
Alewife floater	*Anondonta implicata*
Atlantic spike	*Elliptio producta*
Eastern elliptio	*Elliptio complanata*
Eastern floater	*Pyganodon cataracta*
Northern lance	*Elliptio fisheriana*
Squawfoot	*Strophitus undulatus*
Yellow lance	*Elliptio lanceolata*
Corbiculidae	
Asiatic clam	*Corbicula fluminea*

Table C-7. Aquatic vegetation recorded in the 1995-1997 MBSS, by vegetation type	
Common Name	**Scientific Name**
Submerged	
Larger water-starwort	*Callitriche heterophylla*
Coontail	*Ceratophyllum demersum*
Elodea	*Elodea canadensis*
Hydrilla	*Hydrilla verticillata*
Eurasian watermilfoil	*Myriophyllum spicatum*
Naiad	*Najas* sp.
Riverweed	*Podostemum ceratophyllum*
Curly pondweed	*Potamogeton crispus*
Floating pondweed	*Potamogeton epihydrus*
Small pondweed	*Potamogeton pusillus*
Water celery	*Vallisneria americana*
Horned Pondweed	*Zannichellia palustris*
Emergent	
Common water plantain	*Alisma subcordatum*
Water pennywort	*Hydrocotyle* sp.
Water purslane	*Ludwigia palustris*
Watercress	*Nasturtium officinale*
Arrow arum	*Peltandra virginica*
Pickerelweed	*Pontederia cordata*
Arrow head	*Sagittaria* sp.
Lizards tail	*Saururus cernuus*
Burreed	*Sparganium* sp.
Cattail	*Typha* sp.
Floating	
Duckweed	*Lemna* sp.
Yellow water lily	*Nuphar advena*

APPENDIX D

Interannual Variability Data

Table D-1. Precipitation data for the state of Maryland, 1995-1997

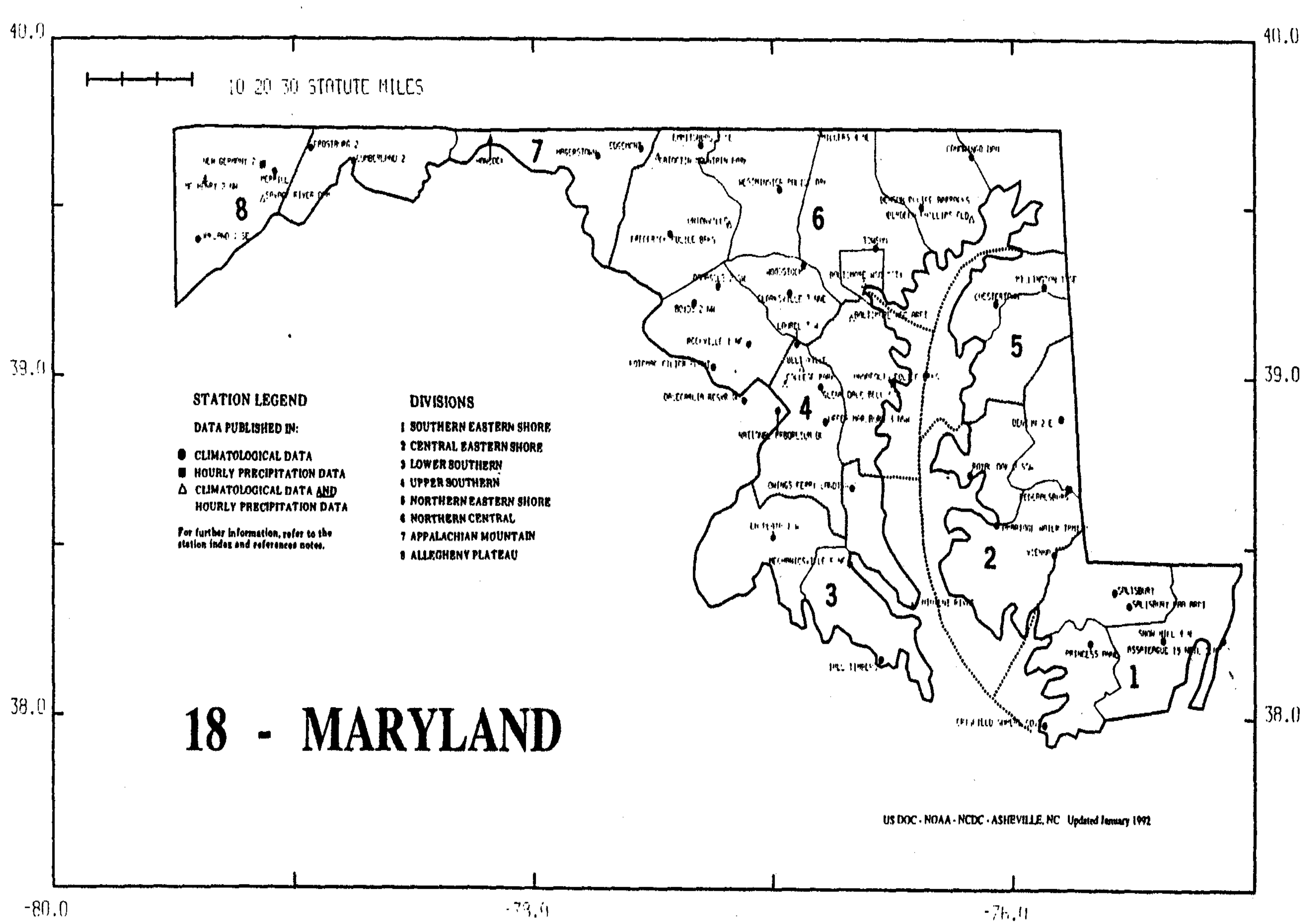
Division	Name	MBSS Basins	Annual Precip (inches)	Departure from Normal (inches)	Departure from Normal (%)
1995 Precipitation data (from NOAA Climatological data annual summary, MD and DE 1995)					
1	Southern Eastern Shore	Nanticoke/Wicomico	35.20	-8.05	-18.6
2	Central Eastern Shore	Nanticoke/Wicomico	41.80	-1.53	-3.5
3	Lower Southern	Lower Potomac	41.40	-1.16	-2.7
4	Upper Southern	Lower Potomac, Patapsco	41.61	-0.87	-2.0
5	Northern Eastern Shore	Chester	44.61	1.92	4.5
6	Northern Central	Patapsco	40.62	-2.59	-6.0
7	Appalachian Mountain	Upper Potomac	37.41	-1.06	-2.8
8	Allegheny Plateau	Youghiogheny, Upper Potomac	37.52	-7.51	-16.7
	Statewide average		40.02	-2.61	-6.1
1996 Precipitation data (from NOAA Climatological data annual summary, MD and DE 1996)					
1	Southern Eastern Shore	none	59.55	16.30	37.7
2	Central Eastern Shore	Choptank	52.22	8.89	20.5
3	Lower Southern	none	52.51	9.95	23.4
4	Upper Southern	Patapsco	57.96	15.48	36.4
5	Northern Eastern Shore	Elk, Choptank	61.26	18.57	43.5
6	Northern Central	Middle Potomac, Patapsco, Gunpowder, Bush, Elk	64.37	21.16	49.0
7	Appalachian Mountain	North Branch Potomac, Middle Potomac	58.59	20.12	52.3
8	Allegheny Plateau	North Branch Potomac	62.00	16.97	37.7
	Statewide average		58.56	15.93	37.6
1997 Precipitation data (from NOAA Climatological data annual summary, MD and DE 1997)					
1	Southern Eastern Shore	Pocomoke	42.38	-0.87	-2.0
2	Central Eastern Shore	Choptank	42.73	-0.60	-1.4
3	Lower Southern	Patuxent	39.40	-3.16	-7.4
4	Upper Southern	Potomac Washington Metro, Patuxent	40.15	-2.33	-5.5
5	Northern Eastern Shore	Choptank	39.87	-2.82	-6.6
6	Northern Central	Susquehanna	34.22	-8.99	-20.8
7	Appalachian Mountain	none	36.59	-1.88	-4.9
8	Allegheny Plateau	Youghiogheny	insuf. Data	insuf. Data	
	Statewide average		39.33	-2.95	-6.9

Table D-2. Stream reaches revisited in multiple years of the 1995-1997 MBSS							
SITE	**BASIN**	**REACH**	**BIBI**	**PHI**	**FIBI**	**NO_3**	**DISCHARGE**
QA-N-098-301-96	CK	QA-N-098	3.00	88.21	4.75	3.72	30.34
QA-N-098-302-96	CK	QA-N-098	3.29	94.18	4.75	3.62	14.67
QA-N-098-307-96	CK	QA-N-098	3.29	81.18	4.25	3.64	20.96
QA-N-098-308-96	CK	QA-N-098	2.71	91.59	4.25	3.65	12.75
QA-N-098-309-96	CK	QA-N-098	2.43	90.61	4.75	3.62	18.01
QA-N-098-302-97	CK	QA-N-098	3.00	56.49	4.50	2.86	8.18
QA-N-098-308-97	CK	QA-N-098	1.86	70.64	4.75	2.90	2.33
QA-N-098-315-97	CK	QA-N-098	1.86	55.13	5.00	2.10	14.02
TA-N-053-201-96	CK	TA-N-053	2.71	25.50	3.50	5.29	0.35
TA-N-053-203-97	CK	TA-N-053	3.29	15.30	2.50	5.96	0.13
BA-P-077-322-95	PP	BA-P-077	3.44	58.96	2.56	1.37	1.38
BA-P-077-315-96	PP	BA-P-077	3.67	93.05	3.00	1.32	6.85
BA-P-478-325-95	PP	BA-P-478	1.67	53.42	2.78	1.87	16.66
BA-P-478-314-96	PP	BA-P-478	2.33	47.80	2.11	2.04	32.76
BC-N-014-216-95	PP	BC-N-014	1.29	65.87	2.50	1.21	0.18
BC-N-014-224-95	PP	BC-N-014	1.86	61.55	3.00	1.07	0.80
BC-N-014-217-96	PP	BC-N-014	1.00	81.02	1.67	0.80	1.10
BC-N-015-219-95	PP	BC-N-015	1.29	90.97	2.56	1.52	32.25
BC-N-015-202-96	PP	BC-N-015	1.00	32.03	1.22	1.68	23.45
BC-P-003-205-95	PP	BC-P-003	1.22	38.77	1.89	2.64	0.44
BC-P-003-228-96	PP	BC-P-003	1.00	48.31	1.22	1.35	1.64
CR-P-152-318-95	PP	CR-P-152	2.78	51.38	3.67	4.60	28.74
CR-P-152-302-96	PP	CR-P-152	2.56			4.76	
CR-P-260-212-95	PP	CR-P-260	3.44	46.78	4.78	5.66	2.04
CR-P-260-210-96	PP	CR-P-260	2.56	34.04	4.56	5.62	2.64
CR-P-362-302-95	PP	CR-P-362	3.67	80.00	4.56	2.17	11.90
CR-P-362-304-95	PP	CR-P-362	3.89	88.08	4.56	2.17	11.90
CR-P-362-317-95	PP	CR-P-362	4.11	42.23	4.78	2.03	4.10
CR-P-362-310-96	PP	CR-P-362	1.67	60.54	3.89	2.17	20.14
CR-P-419-214-95	PP	CR-P-419	2.56	84.73	4.33	4.47	4.20
CR-P-419-227-96	PP	CR-P-419	1.67	88.92	3.89	4.49	22.63
CR-P-999-323-95	PP	CR-P-999	2.56	85.51	3.89	4.81	4.27
CR-P-999-323-96	PP	CR-P-999	4.11	93.44	3.89	4.92	17.00
HO-P-244-310-95	PP	HO-P-244	3.00	71.82	4.11	4.28	9.76
HO-P-244-307-96	PP	HO-P-244	2.11			4.05	
GA-A-062-202-95	YG	GA-A-062	4.56	86.26	4.14	0.68	2.66
GA-A-062-222-95	YG	GA-A-062	4.56	80.32	4.14	0.63	1.92

GA-A-062-203-97	YG	GA-A-062	4.56	77.96	3.86	0.75	1.51

Table D-2. Cont'd

SITE	BASIN	REACH	BIBI	PHI	FIBI	NO_3	DISCHARGE
GA-A-111-316-95	YG	GA-A-111	3.67	38.29	2.71	0.38	1.30
GA-A-111-314-97	YG	GA-A-111	4.11			0.54	
GA-A-407-314-95	YG	GA-A-407	3.89	89.51	3.86	0.33	8.12
GA-A-407-310-97	YG	GA-A-407	3.44	54.44	3.86	0.46	0.99
GA-A-407-312-97	YG	GA-A-407	3.22	62.38	2.71	0.47	2.78
GA-A-407-313-97	YG	GA-A-407	3.67	64.75	3.86	0.48	2.78
GA-A-505-210-95	YG	GA-A-505	3.67	16.75	2.71	0.26	0.50
GA-A-505-218-97	YG	GA-A-505	3.22	43.73	3.29	0.45	0.97



10 20 30 STATUTE MILES
18 - MARYLAND
STATION LEGEND
DATA PUBLISHED IN:
CLIMATOLOGICAL DATA
HOURLY PRECIPITATION DATA
CLIMATOLOGICAL DATA AND HOURLY PRECIPITATION DATA
For further information, refer to the station index and reference notes.
DIVISIONS
1 SOUTHERN EASTERN SHORE
2 CENTRAL EASTERN SHORE
3 LOWER SOUTHERN
4 UPPER SOUTHERN
5 NORTHERN EASTERN SHORE
6 NORTHERN CENTRAL
7 APPALACHIAN MOUNTAIN
8 ALLEGHENY PLATEAU
US DOC - NOAA - NCDC - ASHEVILLE, NC Updated January 1992
40.0
39.0
38.0
-80.0
-76.0

APPENDIX E

Data Summary Tables for Habitat, Water Chemistry, and Fish Populations

Table E-1. Stream habitat characterization, estimated as percentage of stream miles in specific categories, statewide, 1995-1997 MBSS

Variable	Category	% of Stream Miles	Standard Error
Beaver Pond (Y/N)	Y	2.1	1.1
Channelized (Y/N)	Y	17.2	10.2
Instream Habitat	0-5	12.4	3.4
	6-10	27.8	7.6
	11-15	37.7	6.5
	16-20	22.1	5.9
Epifaunal Substrate	0-5	30.7	7.8
	6-10	16.5	6.3
	11-15	35.9	6.4
	16-20	16.9	5.7
Velocity/Depth Diversity	0-5	11.7	5.7
	6-10	48.1	6.5
	11-15	31.9	4.8
	16-20	8.3	
Pool/Glide/Eddy Quality	0-5	9.9	3.2
	6-10	30.5	7.3
	11-15	38.7	5.0
	16-20	20.8	9.4
Riffle Quality	0-5	16.3	7.5
	6-10	34.3	6.8
	11-15	35.9	11.4
	16-20	13.3	6.8
Channel Alteration	0-5	24.0	4.9
	6-10	30.8	5.4
	11-15	22.8	5.8
	16-20	22.4	6.5
Bank Stability	0-5	13.4	4.3
	6-10	34.2	6.1
	11-15	22.9	5.9
	16-20	29.5	9.6
Embeddedness (%)	0-25	26.9	11.7
	26-50	28.6	4.2
	51-75	16.6	4.4
	76-100	27.8	11.1
Channel Flow Status (%)	0-25	2.7	2.8
	26-50	15.4	3.7
	51-75	24.3	6.0
	76-100	57.6	6.8
Shading (%)	0-25	7.7	3.6
	26-50	10.1	5.2
	51-75	22.3	7.9
	76-100	59.9	5.1

Table E-1. Cont'd			
Variable	**Category**	**% of Stream Miles**	**Standard Error**
Riparian Buffer Width (m)	0	28.4	8.3
	1-5	6.5	3.6
	6-18	11.9	3.9
	19-49	12.9	6.7
	50+	40.2	7.1
Riparian Buffer Type	None	26.5	9.7
	Forest	57.8	9.3
	Emergent vegetation	0.3	0.4
	Other vegetation	13.2	3.0
	Other	2.0	1.5
Aesthetic Quality	0-5	10.4	7.8
	6-10	17.2	4.4
	11-15	29.2	5.9
	16-20	43.2	9.2
Remoteness	0-5	27.6	2.5
	6-10	29.4	5.4
	11-15	25.6	4.5
	16-20	17.4	6.1

Table E-2. Percentage of stream miles in each category for water chemistry variables, statewide, 1995-1997 MBSS

Variable (units)	Water Chemistry Level	% of Stream Miles	Standard Error
ANC (μeq/l)	ANC<0	2.2	2.4
	$0 \leq$ ANC ≤ 50	3.6	6.8
	$50 \leq$ ANC < 200	22.3	6.9
	ANC ≥ 200	71.9	9.5
pH spring	pH < 5	2.6	2.5
	$5 \leq$ pH ≤ 6	6.4	2.2
	pH > 6	90.7	4.4
pH summer	pH < 5	1.8	1.7
	$5 \leq$ pH ≤ 6	4.1	1.6
	pH > 6	94.0	3.3
DOC (mg/l)	DOC < 5	79.8	5.6
	$5 \leq$ DOC ≤ 10	14.4	3.5
	DOC > 10	5.8	5.2
SO4 (mg/l)	SO4 < 10	3.6	4.4
	$10 \leq$ SO4 ≤ 50	62.7	4.2
	SO4 > 50	1.6	0.4
NO3-N (mg/l)	NO3 < 0.01	0.4	0.7
	$0.01 \leq$ NO3 ≤ 1	40.9	6.9
	NO3 > 1	58.6	6.8
	NO3 > 7	4.8	2.8
DO (ppm)	DO < 3	2.9	2.6
	$3 \leq$ DO ≤ 5	3.5	3.0
	DO > 5	93.5	3.3

Table E-3. Estimated number of gamefish per stream mile and total abundance across stream order, statewide, 1995-1997 MBSS. Values are given for all gamefish and for harvestable sized gamefish only. Adjusted Density and Total Abundance are estimates adjusted for capture efficiency.

Species	Adjusted Density (Number per Stream Mile)	Std. Error	Adjusted Total Abundance	Std. Error
Esocidae				
Chain pickerel				
all	10.6	6.3	62,662	21,119
legal size	0.8	1.2	4,928	6,593
Salmonidae				
Brook trout				
all	54.0	33.7	317,989	125,043
> 6 inches	9.4	5.1	55,160	13,895
Brown trout				
all	29.2	16.3	172,152	47,173
> 6 inches	7.5	3.9	43,882	9,207
Cutthroat trout				
all	0.1	0.0	346	159
> 6 inches	0.1	0.0	346	159
Rainbow trout				
all	1.3	0.7	7,540	2,169
> 6 inches	1.2	0.7	6,987	2,031
Moronidae				
Striped bass				
all	0.4	0.7	2,518	3,812
legal size	0.0	0.0	0	0
Centrarchidae				
Largemouth bass				
all	52.8	40.3	311,132	183,646
legal size	0.8	0.6	4,530	2,389
Smallmouth bass				
all	6.9	3.6	40,609	8,094
legal size	0.2	0.1	869	175
Total (all gamefish species)				
all	155.4	83.6	914,947	214,372
harvestable size	19.8	10.1	116,700	19,110

Table E-4. Estimated number of nongame fish species per stream mile and total abundance across stream order, statewide, 1995-1997 MBSS. Adjusted Density and Total Abundance are estimates adjusted for capture efficiency.

Species	Adjusted Density	Std. Error	Adjusted Total Abundance	Std. Error
Petromyzontidae				
American brook lamprey	30.2	65.3	178,009	374,561
Least brook lamprey	111.1	55.8	654,127	87,238
Sea lamprey	9.5	5.9	55,857	21,891
Lepisosteidae				
Longnose gar	< 0.1	< 0.1	21	18
Anguillidae				
American eel	190.7	93.4	1,122,758	86,187
Clupidae				
Gizzard shad	< 0.1	< 0.1	223	116
Esocidae				
Redfin pickerel	71.5	40.0	420,873	118,537
Umbridae				
Eastern mudminnow	1,134.5	575.2	6,679,978	1,009,922
Cyprinidae				
Cyprinid hybrid	0.2	0.2	1,295	753
Blacknose dace	1,968.5	990.6	11,590,230	1,600,026
Bluntnose minnow	280.9	138.8	1,653,640	167,008
Central stoneroller	179.8	91.4	1,058,777	165,292
Comely shiner	0.6	0.4	3,639	1,549
Common carp	0.6	0.5	3,247	2,254
Common shiner	124.8	90.0	734,803	648,726
Creek chub	653.0	334.7	3,844,730	648,726
Cutlips minnow	94.5	46.1	556,220	35,196
Eastern silvery minnow	4.5	3	26,514	9,152
Fallfish	78.9	38.3	464,391	20,805
Fathead minnow	80.9	101.4	476,362	550,524
Golden shiner	72.5	57.5	426,980	78,082
Goldfish	0.1	0.1	689	269
Ironcolor shiner	0.5	0.3	2,919	1,128
Longnose dace	318.9	160.0	1,877,414	249,640
Pearl dace	84.4	69.7	497,025	332,517
River chub	41.4		243,787	
Rosyface shiner	3.2	1.7	19,063	4,459
Rosyside dace	487.5	255.3	2,870,653	574,591
Satinfin shiner	36.8	22.5	216,444	80,880
Silverjaw minnow	10.9	6.0	63,986	17,122
Spotfin shiner	9.1	5.3	53,591	17,805
Spottail shiner	94.1	327.5	554,264	1,909,655
Striped shiner	1.7	2.6	10,152	14,506
Swallowtail shiner	161.8	137.1	952,770	662,837

Table E-4. Cont'd				
Species	**Adjusted Density**	**Std. Error**	**Adjusted Total Abundance**	**Std. Error**
Catostomidae				
Creek chubsucker	107.3	59.1	631,485	166,139
Golden redhorse	< 0.1	< 0.1	62	30
Northern hogsucker	34.8	17.5	204,736	27,213
Shorthead redhorse	< 0.1	< 0.1	310	168
White sucker	350.2	178.6	2,061,880	333,393
Ictaluridae				
Brown bullhead	84.1	66.2	495,000	307,642
Channel catfish	< 0.1	< 0.1	79	37
Margined madtom	80.4	40.7	473,100	70,639
Tadpole madtom	61.7	38.4	363,188	142,141
White catfish	< 0.1	< 0.1	229	129
Yellow bullhead	19.4	9.9	114,377	20,001
Aphredoderidae				
Pirate perch	173.2	167.5	1,019,821	853,994
Fundulidae				
Banded killifish	18.3	11.8	107,723	45,576
Mummichog	48.1	37.2	283,159	171,225
Poeciliidae				
Mosquitofish	4.9	3.8	28,594	17,534
Cottidae				
Checkered sculpin	80.8	129.8	475,984	728,873
Mottled sculpin	1,372.7	776.4	8,082,141	2,366,139
Potomac sculpin	243.6	124.7	1,434,325	238,749
Moronidae				
White perch	< 0.1	< 0.1	423	206
Centrarchidae				
Banded sunfish	13.1	10.8	77,256	51,522
Black crappie	3.4	1.9	19,954	5,852
Bluegill	158.6	78.1	934,266	82,394
Bluespotted sunfish	58.5	52.9	344,711	99,515
Flier	0.23	0.14	1,335	513
Green sunfish	91.1	56.9	536,198	212,054
Longear sunfish	< 0.1	< 0.1	279	104
Mud sunfish	0.6	0.4	3,519	1,519
Pumpkinseed	83.3	42.0	490,324	69,870
Redbreast sunfish	83.3	41.6	490,775	58,884
Rock bass	10.6	5.9	62,449	16,799
Warmouth	4.1		24,055	
Lepomis hybrid	1.1	0.7	6,560	2,246

Table E-4. Cont'd

Species	Adjusted Density	Std. Error	Adjusted Total Abundance	Std. Error
Percidae				
Fantail darter	138.4	68.9	814,992	96,320
Glassy darter	0.8	0.5	4,825	1,798
Greenside darter	17.9		105,119	
Johnny darter	13.1	12.7	77,012	64,919
Logperch	1.4	1.4	8,185	6,679
Rainbow darter	< 0.1	< 0.1	124	68
Shield darter	12.8	14.8	75,198	79,209
Stripeback darter	0.1	0.1	580	299
Swamp darter	1.6	1.1	9,286	4,629
Tessellated darter	447.4	295.3	2,634,290	1,182,450
Yellow perch	8.2	9.4	48,352	50,121
Total	10,169	5,055	59,877,675	6,799,193

APPENDIX F

Stressor Matrix

Table F-1. 1995-1997 MBSS Stressors Matrix

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
HA-N-003-204-96	BU	39.46	-76.17	02130705	Aberdeen Proving Grounds	ROMNEY CR MIDDLE BR	2	2482						1.29			48.03
HA-N-009-105-96	BU	39.44	-76.34	02130702	Lower Winters Run	WINTERS RUN UT1	1	103						1.86			26.21
HA-N-018-103-96	BU	39.57	-76.20	02130706	Swan Creek	SWAN CR	1	185						2.43	23.66		
HA-N-036-206-96	BU	39.53	-76.17	02130706	Swan Creek	CARSINS RUN	2	6737		3.89				1.86			
HA-N-040-307-96	BU	39.46	-76.32	02130702	Lower Winters Run	WINTERS RUN	3	33190		3.44				2.71			
HA-N-052-202-96	BU	39.52	-76.13	02130706	Swan Creek	GASHEYS RUN	2	2628		5.00				2.71			
HA-N-067-111-96	BU	39.50	-76.20	02130701	Bush River	CRANBERRY RUN	1	1413		3.22				1.00		6.95	
HA-N-068-301-96	BU	39.51	-76.31	02130704	Bynum Run	BYNUM RUN	3	8329		4.56				2.43			
HA-N-068-308-96	BU	39.50	-76.31	02130704	Bynum Run	BYNUM RUN	3	8422		4.56				1.00			
HA-N-086-201-96	BU	39.53	-76.27	02130701	Bush River	BROAD RUN	2	1971		3.67				2.14			
HA-N-099-305-96	BU	39.48	-76.28	02130704	Bynum Run	BYNUM RUN	3	13326		4.56				1.57			
HA-P-001-205-96	BU	39.58	-76.44	02130703	Atkisson Reservoir	EAST BR	2	4179		5.00				2.11			
HA-P-062-207-96	BU	39.55	-76.34	02130704	Bynum Run	BYNUM RUN	2	2747		2.56				1.89	5.25	8.97	
HA-P-128-104-96	BU	39.55	-76.48	02130703	Atkisson Reservoir	WEST BR WINTERS RUN UT1	1	564	74.00	2.33				3.44	5.78		
HA-P-151-102-96	BU	39.51	-76.34	02130703	Atkisson Reservoir	PLUMTREE RUN	1	1215		2.11				1.67	5.35		46.34
HA-P-164-306-96	BU	39.53	-76.32	02130704	Bynum Run	BYNUM RUN	3	6904		4.11				2.56			
CN-N-004-311-97	CK	39.08	-75.75	02130404	Upper Choptank	TIDY ISLAND CR	3	21137.16		4.00				1.57		6.56	
CN-N-005-103-97	CK	38.93	-75.84	02130404	Upper Choptank	CHOPTANK R UT2	1	2814.31		3.00				2.14		6.34	
CN-N-016-107-97	CK	39.08	-75.79	02130404	Upper Choptank	BROADWAY BR	1	182.06						1.29	6.15	7.07	
CN-N-020-109-96	CK	38.98	-75.84	02130404	Upper Choptank	FORGE BR UT1	1	1685		3.75				1.86	34.72	6.82	
CN-N-024-113-96	CK	38.72	-75.96	02130404	Upper Choptank	SKELETON CR	1	536		2.75			1	2.14	28.99	6.77	
CN-N-030-109-97	CK	39.14	-75.78	02130404	Upper Choptank	HARRINGTON BEAVERDAM DITCH UT2	1	419.33						1.57		7.57	
CN-N-039-108-96	CK	39.13	-75.78	02130404	Upper Choptank	HARRINGTON BEAVERDAM DITCH UT1	1	371		3.75			1	1.29		6.75	
CN-N-043-102-97	CK	38.85	-75.79	02130404	Upper Choptank	HERRING RUN	1	2959.67		2.50				1.29	10.73	7.67	
CN-N-044-207-97	CK	38.88	-75.76	02130404	Upper Choptank	BURRSVILLE BR	2	2382.07						1.57		8.52	
CN-N-046-105-97	CK	39.04	-75.80	02130404	Upper Choptank	OLDTOWN BR	1	879.03		2.25				1.29	10.83	6.43	
CN-N-050-102-96	CK	39.09	-75.77	02130404	Upper Choptank	COOLSPRING BR	1	1053		3.50				1.86		6.89	
CN-N-051-202-96	CK	38.99	-75.78	02130404	Upper Choptank	GRAVELLY BR	2	10850		3.75				1.86		6.88	
CN-N-058-120-97	CK	38.76	-75.95	02130404	Upper Choptank	MITCHELL RUN	1	463.4						2.71		6.36	
CN-S-010-117-97	CK	38.70	-75.90	02130403	Lower Choptank	HUNTING CR	1	6254.24						2.43		6.24	
QA-N-040-206-96	CK	38.98	-75.97	02130405	Tuckahoe Creek	BLOCKSTON BR	2	4233		4.00				1.86		6.92	

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
HA-N-003-204-96	BU									11.40																								
HA-N-009-105-96	BU																8	9			7	8					0.00		GR	6	5		18.50	
HA-N-018-103-96	BU	80.00															10	2	5	7	6	7	6	90				FR	FR				14.25	
HA-N-036-206-96	BU																10		8		3		6					FR	LN		7			
HA-N-040-307-96	BU						2.50										10										10.00	FR	PV	5				
HA-N-052-202-96	BU						2.32															9	5					FR	GR					
HA-N-067-111-96	BU																	10				6	8					FR	FR					
HA-N-068-301-96	BU						2.25						X														3.00	FR	GR	5				
HA-N-068-308-96	BU						2.18												10	10							8.00	FR	PV	5				
HA-N-086-201-96	BU						3.25															6	8					FR	FR	4				
HA-N-099-305-96	BU						2.25															10	9					FR	FR	9				
HA-P-001-205-96	BU						2.81															8						OF	PV					
HA-P-062-207-96	BU						2.18										8	4	6		0	3	5	90				FR	LN	8	10			
HA-P-128-104-96	BU	85.64			192.60	AGR	3.07										6	7	8	7	8	6	6				5.00	OF	LN	10			8.00	
HA-P-151-102-96	BU						2.46							X			8		6	6	10	1					0.00	PV	PV	0	0		13.25	
HA-P-164-306-96	BU						2.16						X					5				6	5	80			0.00	SL	PA	6				PC
CN-N-004-311-97	CK																					10		98				FR	FR		8			
CN-N-005-103-97	CK				188.60	AGR	8.90															10						FR	OF					
CN-N-016-107-97	CK				191.30	AGR		4.30					X				5	3	2	6	6	2		100		20	4.00	OF	CP	7		18.00	9.00	
CN-N-020-109-96	CK				95.40	AGR	4.06											10	8	10	4	5		100			10.00	FR	OF		6			
CN-N-024-113-96	CK				100.30	ORG & AD				15.90								10	4	8	2	9	10	85				FR	CP					
CN-N-030-109-97	CK								25.34																									
CN-N-039-108-96	CK				191.50	ORG & AD				9.10			X	X				6	7		5	2		100		5	4.00	TG	CP	6				
CN-N-043-102-97	CK						6.67						X				6	5	5	5	7	5		90		10	5.00	LN	CP	6			19.75	
CN-N-044-207-97	CK																																	
CN-N-046-105-97	CK				64.10	AD							X				6	5	4	6	6	3		100		10	5.00	OF	CP	6			19.25	
CN-N-050-102-96	CK				167.90	AD							X									7						OF	FR					
CN-N-051-202-96	CK				165.40	AGR	4.40																					FR	FR					
CN-N-058-120-97	CK				90.80	AGR	2.52			16.30																								
CN-S-010-117-97	CK	77.35					8.47																											
QA-N-040-206-96	CK						4.59															5	10	100				FR	CP					

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
QA-N-047-204-96	CK	39.06	-75.87	02130405	Tuckahoe Creek	MASON BR UT2	2	7862		4.00				1.86		7.27	
QA-N-052-202-97	CK	39.07	-75.85	02130405	Tuckahoe Creek	MASON BR	2	10829.34		4.50				1.86		6.26	
QA-N-085-307-97	CK	39.02	-75.89	02130405	Tuckahoe Creek	MASON BR	3	28211.52		4.50				2.14	28.99	6.93	
QA-N-085-312-97	CK	39.02	-75.90	02130405	Tuckahoe Creek	MASON BR	3	28328.19		4.50				2.43	25.92	6.32	
QA-N-098-308-96	CK	39.03	-75.88	02130405	Tuckahoe Creek	MASON BR	3	24341		4.25				2.71		7.20	
QA-N-098-308-97	CK	39.03	-75.88	02130405	Tuckahoe Creek	MASON BR	3	23533.13		4.75				1.86		6.45	
QA-N-098-309-96	CK	39.04	-75.88	02130405	Tuckahoe Creek	MASON BR	3	23268		4.75				2.43		6.86	
QA-N-098-315-97	CK	39.04	-75.88	02130405	Tuckahoe Creek	MASON BR	3	22297.38		5.00				1.86		6.04	
TA-N-011-106-97	CK	38.63	-76.02	02130403	Lower Choptank	EASTERN BR BOLINGBROKE CR	1	367.25		1.75				1.29	16.94	6.37	
TA-N-031-204-97	CK	38.66	-75.99	02130404	Upper Choptank	MILES CR UT1	2	417.73						2.14		7.11	
TA-N-031-208-97	CK	38.66	-75.98	02130404	Upper Choptank	MILES CR UT1	2	268.23						1.00			
TA-N-035-105-96	CK	38.88	-75.98	02130405	Tuckahoe Creek	TUCKAHOE CR UT2	1	1823		4.50				1.57		6.82	
TA-N-048-112-96	CK	38.69	-76.05	02130404	Upper Choptank	MILES CR	1	1118						1.86		6.55	
TA-N-053-201-96	CK	38.84	-76.00	02130404	Upper Choptank	BEAVERDAM BR	2	604		3.50				2.71	25.50	6.60	
TA-N-053-203-97	CK	38.84	-76.00	02130404	Upper Choptank	BEAVERDAM BR	2	673.67		2.50				3.29	15.30	6.33	
TA-N-070-101-96	CK	38.65	-76.07	02130403	Lower Choptank	TRAPPE CR UT1	1	405						2.14			
TA-N-071-107-96	CK	38.85	-76.01	02130404	Upper Choptank	BEAVERDAM BR	1	308						2.43		6.81	
TA-N-999-108-97	CK	38.75	-76.06	02130403	Lower Choptank	TRED AVON R UT1	1	274.76						2.14	6.35	8.30	
KE-N-045-108-95	CR	39.31	-75.78	02130510	Upper Chester River	CYPRESS BR UT1	1	1386.96		1.00	1		1	1.29	7.11	7.16	
KE-N-054-114-95	CR	39.14	-76.23	02130505	Lower Chester River	GRAYS INN CR	1	811.86	50.00	1.00	1			1.86	3.45		
KE-N-067-213-95	CR	39.19	-76.17	02130506	Langford Creek	WEST FORK LANGFORD CR	2	1887.2		2.75				1.86			
KE-N-096-102-95	CR	39.19	-76.22	02130505	Lower Chester River	SWAN CR	1	356.55		2.75			1	1.86		7.34	
KE-N-128-122-95	CR	39.29	-76.03	02130509	Middle Chester River	MORGAN CR UT1	1	865.07		4.00				1.57	24.67	6.72	
QA-N-030-128-95	CR	38.99	-76.08	02130503	Wye River	WYE EAST R UT1	1	668.41		2.50				2.43	3.31	6.45	
QA-N-031-202-95	CR	39.09	-76.05	02130508	Southeast Creek	ISLAND CREEK	2	2591		2.50				1.57	34.47	7.84	
QA-N-031-203-95	CR	39.08	-76.05	02130508	Southeast Creek	ISLAND CREEK	2	2558.81		4.25				2.14	41.73		
QA-N-031-225-95	CR	39.08	-76.05	02130508	Southeast Creek	ISLAND CREEK	2	2542.39		3.50				1.57	34.47		
QA-N-041-109-95	CR	39.19	-75.78	02130510	Upper Chester River	ANDOVER BR	1	3125.31		3.75				1.86	7.48	6.73	
QA-N-041-113-95	CR	39.17	-75.79	02130510	Upper Chester River	ANDOVER BR	1	952.47		2.50				1.57	2.30	6.82	
QA-N-042-116-95	CR	39.05	-76.06	02130507	Corsica River	GRAVEL RUN	1	1464.49		4.00				2.14	21.36	6.85	
QA-N-059-125-95	CR	39.20	-75.82	02130510	Upper Chester River	UNICORN BR UT1	1	828.53		3.75				2.14	12.06	6.78	

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
QA-N-047-204-96	CK						4.57						X													15	4.00	OF	PA					
QA-N-052-202-97	CK												X	X				7				4		95		10	0.00		CP	7	6			
QA-N-085-307-97	CK						3.18						X					7	5	8				80		20	2.00	OF	LN	6				
QA-N-085-312-97	CK						3.53						X				10	8	5	7	7	8		95		10	10.00	OF	FR	3				
QA-N-098-308-96	CK				193.70	AGR	3.65						X									5					14.00	OF	FR	6				
QA-N-098-308-97	CK						2.90						X						10			7				20		TG	FR	6				
QA-N-098-309-96	CK						3.62						X									5				20		OF	FR					
QA-N-098-315-97	CK						2.10			10.90			X						10	10		6				20	14.00	TG	FR	2				
TA-N-011-106-97	CK	79.21					2.47		30.31								5	5	6	7	7	9	3	80				FR	CP				11.00	
TA-N-031-204-97	CK									18.10																								
TA-N-031-208-97	CK		4.10		-124.60	ORG & AD				31.60																								
TA-N-035-105-96	CK						12.92												9		9			95			3.00	OF	CP	10	8			
TA-N-048-112-96	CK				150.40	AGR	5.91																											
TA-N-053-201-96	CK	85.60					5.29						X						5	10	6	4	10	100			10.00	FR	CP			18.00	17.00	
TA-N-053-203-97	CK	82.48					5.96										7	8	5	7	8	10		80			13.00	FR	OF	5			8.50	
TA-N-070-101-96	CK				35.60	AD			48.01																									
TA-N-071-107-96	CK	85.71					3.74																											
TA-N-999-108-97	CK							3.60									4	4	3	6	6	5		100				FR	PV	6			4.00	
KE-N-045-108-95	CR		4.91	4.52	7.58	ORG		3.20		21.00							5	10	2	6	3			100	20			FR	FR				3.00	
KE-N-054-114-95	CR								29.42	20.00			X				6	3	3	2	6	4		100				FR	FR	6	6	18.00	12.75	
KE-N-067-213-95	CR						6.27						X					6	8		0			100				OF	FR					
KE-N-096-102-95	CR				100.36	ORG & AD		0.80		20.00			X			X		5	3		0	4		100				OF	OF					
KE-N-128-122-95	CR	86.18															7	3	6	4	6		6				2.00	OF	PV	1				
QA-N-030-128-95	CR																3	3	4	1	5	4	6	100				OF	LN	6		19.00	13.00	
QA-N-031-202-95	CR							1.20		9.00		X	X				5	3	3		0	7	2	100				FR		6				
QA-N-031-203-95	CR							2.70		8.00			X				6	5	6		5	3	4	100				FR	CP	6				
QA-N-031-225-95	CR							4.20		9.00			X				6	2	6		1	4	4	100				FR	CP					
QA-N-041-109-95	CR							1.50		11.00			X				6	5	5	6	6	5	4	100				PA	PA	5	5			
QA-N-041-113-95	CR							4.40		16.00			X				2	1	1	3	0	4		100			5.00	OF	PA	6	5		17.75	
QA-N-042-116-95	CR	82.17					3.28						X		X		10	1	8	9	6		6				10.00	OF	PK	1	0		18.00	
QA-N-059-125-95	CR							2.10		16.00			X				6	4	5	6	6	5		100	20			OF	OR	6			5.75	PC

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
QA-N-066-207-95	CR	39.09	-76.06	02130508	Southeast Creek	ISLAND CREEK	2	3454.8		3.25				2.71			
QA-N-071-110-95	CR	39.10	-76.06	02130508	Southeast Creek	ISLAND CREEK UT1	1	489.8						2.43		6.60	
QA-N-086-126-95	CR	38.97	-76.05	02130503	Wye River	WYE EAST R UT2	1	1291.79	50.00	2.50				2.14	6.22	7.06	
CE-N-040-119-96	EL	39.49	-75.80	02130602	Bohemia River	LABBIDE MILL CR	1	530		2.75				1.29			
CE-P-004-102-96	EL	39.63	-75.97	02130608	Northeast River	STONY RUN	1	1455		4.33				2.33			
CE-P-009-303-96	EL	39.69	-75.83	02130606	Big Elk Creek	BIG ELK CR	3	29559		4.11				2.56			
CE-P-012-210-96	EL	39.63	-76.04	02130609	Furnace Bay	PRINCIPIO CR	2	5068		4.78				2.56			
CE-P-012-212-96	EL	39.63	-76.04	02130609	Furnace Bay	PRINCIPIO CR	2	4919		4.78				2.56			
CE-P-020-118-96	EL	39.63	-75.89	02130605	Little Elk Creek	WEST BR LAUREL RUN	1	947		2.33				2.56	23.99		
CE-P-038-205-96	EL	39.68	-75.99	02130608	Northeast River	NORTHEAST CR	2	10646		3.89				2.78			
CE-P-038-209-96	EL	39.67	-75.99	02130608	Northeast River	NORTHEAST CR	2	11479		3.67				2.11		6.38	
CE-P-046-207-96	EL	39.63	-75.95	02130608	Northeast River	NORTHEAST CR	2	15113		3.67				2.11			
CE-P-081-114-96	EL	39.64	-75.87	02130605	Little Elk Creek	LITTLE ELK CR	1	17872		4.33				1.89		6.21	
CE-P-999-105-96	EL	39.66	-75.81	02130607	Christina River	WEST BR	1	886		3.00				2.56		6.88	
BA-P-015-120-96	GU	39.48	-76.70	02130805	Loch Raven Reservoir	BAISMANS RUN	1	454		1.89		1		4.33			
BA-P-055-103-96	GU	39.53	-76.56	02130804	Little Gunpowder Falls	PARKER BR UT1	1	177						2.56	5.25		
BA-P-057-209-96	GU	39.51	-76.60	02130805	Loch Raven Reservoir	GREENE BR	2	2225		2.78				3.44	20.13		
BA-P-065-119-96	GU	39.59	-76.72	02130805	Loch Raven Reservoir	BUSH CABIN RUN	1	626		1.89		1		3.00	37.81		
BA-P-103-124-96	GU	39.54	-76.62	02130805	Loch Raven Reservoir	CARROLL BR UT1	1	144						2.78	18.84		
BA-P-116-114-96	GU	39.60	-76.75	02130806	Prettyboy Reservoir	PRETTYBOY BR	1	90						1.67	12.00		
BA-P-124-302-96	GU	39.68	-76.70	02130805	Loch Raven Reservoir	LITTLE FLS	3	7054		3.22				2.78			
BA-P-143-104-96	GU	39.49	-76.75	02130805	Loch Raven Reservoir	WATERSPOUT RUN	1	948		2.78				4.33			
BA-P-203-215-96	GU	39.43	-76.52	02130802	Lower Gunpowder Falls	COWEN RUN	2	1913		3.00				2.78			
BA-P-302-115-96	GU	39.47	-76.77	02130805	Loch Raven Reservoir	COUNCILMANS RUN	1	605		2.11				3.67	11.57		
BA-P-315-301-96	GU	39.47	-76.49	02130802	Lower Gunpowder Falls	LONG GREEN CR	3	5180		2.56				2.33			
BA-P-403-106-96	GU	39.49	-76.69	02130805	Loch Raven Reservoir	OREGON BR	1	1423		2.11				3.00			
BA-P-427-107-96	GU	39.44	-76.49	02130802	Lower Gunpowder Falls	LONG GREEN CR UT1	1	262						2.33	39.75		
CH-S-020-322-95	LP	38.59	-76.84	02140108	Zekiah Swamp	ZEKIAH SWAMP	3	12572.79		4.25				2.71			
CH-S-033-314-95	LP	38.58	-77.10	02140111	Mattawoman Creek	MATTAWOMAN CR	3	40507.05		3.50				2.71		6.72	
CH-S-039-224-95	LP	38.65	-77.08	02140102	Potomac River (Middle-tidal)	MILL SWAMP	2	1723.81		2.00				4.43	34.97		
CH-S-080-222-95	LP	38.60	-77.06	02140111	Mattawoman Creek	MATTAWOMAN CR	2	31253.76		1.00				2.43	6.96	6.43	

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
QA-N-066-207-95	CR									9.00								2	5		0	5	5	100				FR	CP					
QA-N-071-110-95	CR									19.00																								
QA-N-086-126-95	CR							1.10		20.00							7	5	3	3	0	5	10	100				FR	CP				16.75	
CE-N-040-119-96	EL	91.13					7.64											5	10		0			99		25		FR	PA	10				
CE-P-004-102-96	EL												X									7						FR	PV	2				
CE-P-009-303-96	EL						3.08																10					FR	DI					
CE-P-012-210-96	EL	80.17					4.03																					FR	OF					
CE-P-012-212-96	EL	80.28					4.26											6									5.00	FR	PA	10				DM
CE-P-020-118-96	EL				138.90	AD											9	5	7		6	5	6				0.00	SL	FR	6	6			
CE-P-038-205-96	EL	76.21					3.47											9					5				0.00	PA	PA					
CE-P-038-209-96	EL	76.29					3.26											7				5						FR	LN					
CE-P-046-207-96	EL						3.07																					FR	FR					
CE-P-081-114-96	EL						2.42						X							10								FR	TG	10				
CE-P-999-105-96	EL				185.40	AD												6			7	7	9				0.00		SL	7				
BA-P-015-120-96	GU				194.50	AD	2.55												10	10			10					FR	FR				16.75	
BA-P-055-103-96	GU																5	6	6	6	7	3	3	90				FR	FR	7			10.75	
BA-P-057-209-96	GU						2.30						X				10	10	7	7		6					0.00	DI	LN	1				
BA-P-065-119-96	GU	86.58					4.58												9	8		10						FR	FR				15.75	
BA-P-103-124-96	GU	88.19					2.71										10		8	8	10	9	8					LN	LN	5			17.50	
BA-P-116-114-96	GU	91.11					4.82										10		6	9	7	6	3				10.00	FR	CP				5.50	
BA-P-124-302-96	GU						4.67																					FR	FR	10				
BA-P-143-104-96	GU																		10			8	10				5.00	FR	PA				16.00	
BA-P-203-215-96	GU																					9	6				3.00	OF	LN	7				
BA-P-302-115-96	GU												X				10		6	5	6	4	7				3.00	OF	CP	6			7.50	DM
BA-P-315-301-96	GU	75.19					4.00										8	6				4	3			25	0.00	PA	PV	5				DM
BA-P-403-106-96	GU						2.41															6	4				10.00	FR	OF	6	6			
BA-P-427-107-96	GU						4.85															7	10					FR	LN					
CH-S-020-322-95	LP				193.55	AD												8	8		2	5	8		20			FR	FR					
CH-S-033-314-95	LP				107.92	AD																10	7				10.00	FR	RR		7			
CH-S-039-224-95	LP				109.99	AD											7		8	8	10	8	7				2.00	FR	DI	6				
CH-S-080-222-95	LP				39.95	AD		1.80									7	3	1	2	0	5		100				FR	FR				15.00	

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
CH-S-105-119-95	LP	38.51	-77.17	02140110	Nanjemoy Creek	JANE BERRY'S RUN ut1	1	401.12		3.25				2.71	18.55		
CH-S-139-116-95	LP	38.64	-76.79	02140108	Zekiah Swamp	ZEKIAH SWAMP RUN	1	1664.1		2.25				1.86	13.28	7.03	
CH-S-139-118-95	LP	38.67	-76.79	02140108	Zekiah Swamp	ZEKIAH SWAMP RUN	1	70.27						1.00			45.03
CH-S-156-206-95	LP	38.48	-76.85	02140107	Gilbert Swamp	GILBERT RUN	2	1921.29		4.00				1.86	15.59	6.12	
CH-S-177-129-95	LP	38.49	-77.22	02140110	Nanjemoy Creek	BEAVER DAM CR	1	886.24		2.75			1	2.71		6.41	
CH-S-188-134-95	LP	38.55	-76.81	02140108	Zekiah Swamp	MILL DAM RUN	1	258.87						2.43	18.88	6.71	
CH-S-213-120-95	LP	38.40	-77.19	02140110	Nanjemoy Creek	NANJEMOY CR UT1	1	493.47		1.75				1.00	3.84	6.41	
CH-S-270-318-95	LP	38.47	-76.85	02140107	Gilbert Swamp	GILBERT SWAMP RUN	3	11676.13		2.50				3.86	13.54		
CH-S-293-136-95	LP	38.58	-76.90	02140108	Zekiah Swamp	PINEY BR UT1	1	281.11	68.00		1			2.71	1.16		
PG-S-005-220-95	LP	38.63	-77.04	02140111	Mattawoman Creek	MATTAWOMAN CR	2	28038.91						1.57		6.26	
PG-S-032-209-95	LP	38.65	-76.89	02140111	Mattawoman Creek	MATTAWOMAN CR	2	8470.54		2.25				2.43		6.84	
SM-S-007-138-95	LP	38.25	-76.44	02140103	St. Mary's River	PEMBROOK RUN	1	453.41	71.00	1.00				2.43	4.74		27.77
SM-S-036-107-95	LP	38.32	-76.75	02140105	St. Clement Bay	DYNARD RUN	1	903.81		2.50				3.57	33.24		
SM-S-104-126-95	LP	38.39	-76.68	02140105	St. Clement Bay	ST CLEMENS CR UT2	1	125.25						2.43	10.73	6.50	26.89
SM-S-116-214-95	LP	38.39	-76.85	02140106	Wicomico River	BUDDS CR	2	3188.51						2.14		6.24	
SM-S-209-105-95	LP	38.29	-76.69	02140105	St. Clement Bay	CECIL CR	1	590.37		1.00				2.71	14.06		
CR-P-019-248-96	MP	39.63	-77.03	02140304	Double Pipe Creek	BEAR BR	2	2314		1.29				2.33			
CR-P-021-329-96	MP	39.55	-77.17	02140304	Double Pipe Creek	SAM'S CR	3	10743		2.71				1.00			
CR-P-035-216-96	MP	39.68	-77.08	02140304	Double Pipe Creek	SILVER RUN	2	4849		4.14				1.00		6.76	
CR-P-094-349-96	MP	39.56	-77.07	02140304	Double Pipe Creek	TURKEY FOOT RUN	3	7338		4.43				1.67			
CR-P-116-316-96	MP	39.65	-77.23	02140303	Upper Monocacy River	PINEY CR	3	20936		3.00				1.44		7.30	
CR-P-116-327-96	MP	39.65	-77.23	02140303	Upper Monocacy River	PINEY CR	3	20988		3.29				1.22		7.13	
CR-P-142-324-96	MP	39.69	-77.15	02140303	Upper Monocacy River	PINEY CR	3	11930		3.86				2.78	31.34		
CR-P-156-314-96	MP	39.71	-77.11	02140303	Upper Monocacy River	PINEY CR	3	6949		5.00				2.78		6.63	
CR-P-156-361-96	MP	39.72	-77.11	02140303	Upper Monocacy River	PINEY CR	3	6919		4.43				2.56			
CR-P-158-123-96	MP	39.54	-77.13	02140304	Double Pipe Creek	PRIESTLAND BR	1	95			1			1.44	7.00	9.97	
CR-P-162-207-96	MP	39.62	-77.15	02140304	Double Pipe Creek	MEADOW BR	2	1198		2.14				1.67		6.63	
CR-P-243-333-96	MP	39.66	-77.00	02140304	Double Pipe Creek	BIG PIPE CR	3	12950		5.00				2.33			
CR-P-249-103-96	MP	39.60	-77.20	02140304	Double Pipe Creek	BIG PIPE CR UT1	1	197			1			2.33	7.99		
CR-P-249-113-96	MP	39.60	-77.20	02140304	Double Pipe Creek	BIG PIPE CR UT1	1	119	73.00		1			2.56	2.48		
CR-P-263-332-96	MP	39.57	-77.07	02140304	Double Pipe Creek	LITTLE PIPE CR	3	6629		2.71				2.33	4.23		

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
CH-S-105-119-95	LP				107.50	AD											6	4		6	8		7	80				FR	DI	3	6			
CH-S-139-116-95	LP				17.08	AD		2.50								X	6	2	3	7	7	5		90				FR	FR				18.00	
CH-S-139-118-95	LP						52.87		31.02	120.00																								
CH-S-156-206-95	LP				161.41	AD							X				5	5	10	6		8	3	90				FR	HO		9		13.75	
CH-S-177-129-95	LP				19.12	AD		1.20		8.00									4		0			100				FR	FR					
CH-S-188-134-95	LP				76.66	AD											6	2	6	10	10			100				FR	PA	8			10.25	
CH-S-213-120-95	LP		4.95		-11.44	AD		0.30									4	1	1	3	0			100				FR	LO	9			17.75	
CH-S-270-318-95	LP				174.49	AD							X				6		4	4	8	8	4					FR	OF	10		17.00	3.75	
CH-S-293-136-95	LP			4.86	17.36	AD											0	0	3	1	2	2	8	100			0.00		HO	0	1	12.00	5.50	
PG-S-005-220-95	LP		4.94		-6.42	AD																												
PG-S-032-209-95	LP				130.69	AD		3.20									6	5										FR	HO	8				
SM-S-007-138-95	LP				50.89	AD		2.20									5	4	2	1	6		7	100				FR	FR				6.75	
SM-S-036-107-95	LP																7	6	8	6	10	7	10					FR	FR				9.75	
SM-S-104-126-95	LP				69.82	AD											5	3	6	6	6	5	7	95				FR	FR	6			10.00	
SM-S-116-214-95	LP				72.17	AD																												
SM-S-209-105-95	LP				107.35	AD		3.50									3	1	6	8	2	4	5	100				FR	CP	6	10			
CR-P-019-248-96	MP	80.64					5.19											10				10	8				0.00		PA	7				
CR-P-021-329-96	MP	77.88					5.36												10		7	5					0.00			7				
CR-P-035-216-96	MP						3.25																					FR	OF					
CR-P-094-349-96	MP						5.56																10				0.00		CP	2				
CR-P-116-316-96	MP	81.76					4.03															10	7				4.00	FR	CP					
CR-P-116-327-96	MP	81.71					4.02																7				0.00		CP					
CR-P-142-324-96	MP	81.45					2.98							X				7			10	5	6	85			0.00		PA	8	9			
CR-P-156-314-96	MP	82.66					4.57																8				0.00		PA					
CR-P-156-361-96	MP	82.63					4.60																9				0.00		PA					
CR-P-158-123-96	MP	96.84					23.73		44.72				X				8		6	6	10	3	6				0.00		PV	3	10	17.00	5.75	
CR-P-162-207-96	MP	83.81					8.10															9					0.00		PA				16.75	
CR-P-243-333-96	MP						3.61																7					TG	FR					
CR-P-249-103-96	MP	88.32					4.44		32.35								7	10	7		8		8					FR	PA				6.25	
CR-P-249-113-96	MP	87.39					6.41		35.34								5	7	6		2	9	9					FR	PA		9	15.00	5.75	
CR-P-263-332-96	MP						6.90										9	10	8		0		10				10.00	OF	PV	4	9			

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
CR-P-274-104-96	MP	39.58	-77.11	02140304	Double Pipe Creek	ROOP BR	1	309		1.00				2.11			
CR-P-295-128-96	MP	39.58	-77.01	02140304	Double Pipe Creek	COPPS BR	1	291						1.44	3.41		
CR-P-365-219-96	MP	39.60	-77.09	02140304	Double Pipe Creek	MEADOW BR	2	4803		3.86				2.56			
CR-P-400-144-96	MP	39.64	-77.15	02140304	Double Pipe Creek	BIG PIPE CR UT2	1	114			1			1.22	3.69		
CR-P-406-102-96	MP	39.67	-77.16	02140303	Upper Monocacy River	PINEY CR UT2	1	422		3.00				1.44	27.92	6.52	
CR-P-434-138-96	MP	39.50	-77.11	02140304	Double Pipe Creek	SAMS CR UT1	1	156			1			2.11	2.48	9.53	
FR-B-032-206-96	MP	39.70	-77.46	02140303	Upper Monocacy River	FRIENDS CR	2	1300		3.00				1.89			
FR-B-046-127-96	MP	39.51	-77.51	02140305	Catoctin Creek	LITTLE CATOCTIN CR 1 UT1	1	301		1.00	1			3.22	8.95		
FR-B-076-118-96	MP	39.35	-77.62	02140301	Potomac River (Frederick County)	LITTLE CATOCTIN CR 2 UT1	1	210						1.67	19.80		
FR-B-081-229-96	MP	39.63	-77.46	02140303	Upper Monocacy River	HUNTING CR	2	2427		2.71		1		2.11		6.11	
FR-B-085-212-96	MP	39.49	-77.57	02140305	Catoctin Creek	CATOCTIN CR	2	22944						1.44		6.43	
FR-B-133-222-96	MP	39.66	-77.48	02140303	Upper Monocacy River	OWENS CR	2	1229		4.14		1		2.11			
FR-B-164-137-96	MP	39.62	-77.53	02140305	Catoctin Creek	MIDDLE CR	1	762		2.71				2.11	26.70		
FR-P-005-141-96	MP	39.44	-77.49	02140302	Lower Monocacy River	ROCK CR	1	551		1.00				1.44	14.84		
FR-P-009-341-96	MP	39.71	-77.32	02140303	Upper Monocacy River	FLAT RUN	3	6702		3.86				1.44			
FR-P-009-347-96	MP	39.71	-77.32	02140303	Upper Monocacy River	FLAT RUN	3	6074		3.57				1.00		6.38	
FR-P-015-304-96	MP	39.32	-77.33	02140302	Lower Monocacy River	BENNET CR	3	16580		4.71				2.33			
FR-P-038-139-96	MP	39.70	-77.36	02140303	Upper Monocacy River	TURKEY CR	1	1441		1.00				2.56			
FR-P-046-227-96	MP	39.56	-77.18	02140304	Double Pipe Creek	HAINES BR	2	1967		2.14				1.67		6.13	
FR-P-050-354-96	MP	39.49	-77.32	02140302	Lower Monocacy River	CABBAGE RUN	3	4448		2.71				2.11			
FR-P-093-237-96	MP	39.49	-77.44	02140303	Upper Monocacy River	TUSCARORA CR	2	7693		1.57				2.56	23.62		
FR-P-093-238-96	MP	39.49	-77.43	02140303	Upper Monocacy River	TUSCARORA CR	2	7712		1.57				2.56	10.37		
FR-P-100-117-96	MP	39.39	-77.48	02140302	Lower Monocacy River	BALLENGER CR UT1	1	436		2.43				3.89	19.48		
FR-P-103-230-96	MP	39.38	-77.46	02140302	Lower Monocacy River	BALLENGER CR	2	2598		3.00				2.78	11.57		
FR-P-111-134-96	MP	39.66	-77.27	02140303	Upper Monocacy River	MONOCACY R UT3	1	315		2.43				1.00	6.12	6.86	
FR-P-116-221-96	MP	39.50	-77.29	02140302	Lower Monocacy River	CABBAGE RUN	2	2138		3.29				2.33	17.04	6.01	
FR-P-156-217-96	MP	39.43	-77.18	02140302	Lower Monocacy River	SOUTH FORK LINGANORE CR	2	4374		3.86				2.56			
FR-P-156-234-96	MP	39.43	-77.19	02140302	Lower Monocacy River	SOUTH FORK LINGANORE CR	2	4865		4.14				2.78			
FR-P-168-218-96	MP	39.33	-77.47	02140301	Potomac River (Frederick County)	TUSCARORA CR	2	2685		2.14				1.22	25.13		
FR-P-214-303-96	MP	39.59	-77.34	02140303	Upper Monocacy River	OWENS CR	3	25147		4.43				2.11			
FR-P-214-342-96	MP	39.59	-77.34	02140303	Upper Monocacy River	OWENS CR	3	25485		4.71				1.67			

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
CR-P-274-104-96	MP	90.29					10.25										8					7	8					OF	CP	10			18.75	
CR-P-295-128-96	MP	76.29					4.01										6	10	6		6	8	4	90		20	0.00		PA	6			10.50	
CR-P-365-219-96	MP	78.26					5.01															10	6			10	0.00		PA	5				
CR-P-400-144-96	MP	85.96					2.65		27.21								8		6	1	6	5	8	80		4	0.00		CP	2	7	15.00	2.75	
CR-P-406-102-96	MP	90.52					5.54		28.49										10				8				0.00		CP	3				
CR-P-434-138-96	MP	80.13					5.80										6	5	6		6	2	1	80				FR	FR		3		14.00	
FR-B-032-206-96	MP																	5	10								10.00	FR	PK		2		18.50	
FR-B-046-127-96	MP																6		7	6	10						0.00	PA				16.00	8.25	
FR-B-076-118-96	MP	79.05					3.32											4	9	9	8	7					5.00	FR	OF				10.00	
FR-B-081-229-96	MP																		10									FR	LN	6				AC
FR-B-085-212-96	MP																																	
FR-B-133-222-96	MP																		10									FR	FR	5				
FR-B-164-137-96	MP																	4	9	10	10							FR	FR				11.75	
FR-P-005-141-96	MP												X					7			5			100			14.00	FR	PV	4	5			
FR-P-009-341-96	MP								27.17																		3.00	FR	LN	7	6			
FR-P-009-347-96	MP								26.26									10					8				0.00		DI	4	6			
FR-P-015-304-96	MP						3.71															10	5				0.00		OF	2				
FR-P-038-139-96	MP																		10	10							6.00	LN	FR	7				
FR-P-046-227-96	MP	87.95					7.71		26.44														6			20	0.00		PA	4				
FR-P-050-354-96	MP						2.28		114.45													6	6			15	0.00		PA	6				
FR-P-093-237-96	MP																	5	9								0.00		PA	6	10		16.75	
FR-P-093-238-96	MP																	4	8		5	5				20	0.00		PA	3	10			
FR-P-100-117-96	MP						2.39										9	5	9	10		8					0.00		CP		10		19.00	
FR-P-103-230-96	MP						4.54						X				6	6	7	8		7	8				0.00		PV	5	7			
FR-P-111-134-96	MP	94.92					7.96		28.01								10	6	6		8	5	4	90		10	0.00		PA	6			11.25	
FR-P-116-221-96	MP						2.71										8		9			10	5			10	0.00		PA	3	3			
FR-P-156-217-96	MP						3.10										10					10						OF	FR					
FR-P-156-234-96	MP						3.01															9					0.00		PA	9				
FR-P-168-218-96	MP						5.51		25.86				X					7	9			6	10	100			3.00	FR	CP	7	9			
FR-P-214-303-96	MP																						9					FR	CP					
FR-P-214-342-96	MP																	4				6	8					FR	CP					

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
FR-P-223-225-96	MP	39.56	-77.21	02140304	Double Pipe Creek	BEAVER DAM CR	2	3927		2.43				2.56			
FR-P-223-240-96	MP	39.56	-77.21	02140304	Double Pipe Creek	BEAVER DAM BR	2	3570		1.57				1.44	27.51	7.30	
FR-P-258-202-96	MP	39.51	-77.38	02140303	Upper Monocacy River	FISHING CR	2	5107		3.57				2.56			
FR-P-258-243-96	MP	39.51	-77.38	02140303	Upper Monocacy River	FISHING CR	2	5046		3.57				1.89		6.71	
FR-P-261-122-96	MP	39.60	-77.39	02140303	Upper Monocacy River	HUNTING CR UT1	1	719		3.29				1.22	4.07	6.90	
FR-P-263-311-96	MP	39.28	-77.49	02140301	Potomac River (Frederick County)	TUSCARORA CR	3	10274		2.71				1.89		6.21	
FR-P-265-335-96	MP	39.72	-77.29	02140303	Upper Monocacy River	MIDDLE CR	3	16053		4.14				1.44			
FR-P-265-351-96	MP	39.72	-77.29	02140303	Upper Monocacy River	MIDDLE CR	3	15993		4.43				2.11			
FR-P-275-239-96	MP	39.36	-77.26	02140302	Lower Monocacy River	CHURCH BR OF BUSH CR	2	3108		4.71				2.56			
FR-P-277-115-96	MP	39.39	-77.48	02140302	Lower Monocacy River	BALLENGER CR UT2	1	663		2.14				2.56	18.53		
FR-P-290-121-96	MP	39.30	-77.50	02140301	Potomac River (Frederick County)	TUSCARORA CR UT1	1	442		1.57				1.67	7.99	7.58	
FR-P-294-313-96	MP	39.57	-77.39	02140303	Upper Monocacy River	HUNTING CR	3	14748		3.57				1.89		6.18	
FR-P-294-357-96	MP	39.57	-77.39	02140303	Upper Monocacy River	HUNTING CR	3	14497		3.86				2.56		6.46	
FR-P-298-308-96	MP	39.61	-77.34	02140303	Upper Monocacy River	OWENS CR	3	19413		4.14				2.78			
FR-P-300-130-96	MP	39.58	-77.36	02140303	Upper Monocacy River	MONOCACY R UT2	1	834		1.29				1.00	5.67	6.73	
FR-P-302-334-96	MP	39.64	-77.38	02140303	Upper Monocacy River	OWENS CR	3	9961		4.43				1.67			
FR-P-319-352-96	MP	39.61	-77.36	02140303	Upper Monocacy River	OWENS CR	3	16950		5.00				2.56			
FR-P-321-214-96	MP	39.43	-77.20	02140302	Lower Monocacy River	WOODVILLE BR	2	4427		4.43				2.33			
FR-P-335-110-96	MP	39.44	-77.40	02140302	Lower Monocacy River	MONOCACY R UT1	1	502		2.43				1.44	3.55		
FR-P-349-204-96	MP	39.38	-77.47	02140302	Lower Monocacy River	BALLENGER CR	2	3530		4.43				2.33			
FR-P-354-321-96	MP	39.25	-77.48	02140301	Potomac River (Frederick County)	TUSCARORA CR	3	12770		3.00				2.78		6.34	
FR-P-371-132-96	MP	39.65	-77.32	02140303	Upper Monocacy River	MOTTER'S RUN	1	758		1.57				1.22	8.95	6.13	
FR-P-377-242-96	MP	39.30	-77.28	02140302	Lower Monocacy River	BENNETT CR	2	6295		3.86				2.33			
FR-P-388-208-96	MP	39.45	-77.15	02140302	Lower Monocacy River	TALBOT BR	2	3036		3.57				1.67			
FR-P-388-246-96	MP	39.45	-77.14	02140302	Lower Monocacy River	TALBOT BR	2	2736		4.14				2.33	39.75		
FR-P-394-317-96	MP	39.49	-77.31	02140302	Lower Monocacy River	CABBAGE RUN	3	4093		3.00				1.89		6.90	
FR-P-399-126-96	MP	39.48	-77.15	02140302	Lower Monocacy River	WELDON CR UT1	1	228						1.67	17.62		
FR-P-409-210-96	MP	39.44	-77.35	02140302	Lower Monocacy River	ADDISON RUN	2	1584		1.57				2.56	16.75	6.11	
FR-P-462-346-96	MP	39.52	-77.17	02140304	Double Pipe Creek	CLEMSON BR	3	2128		1.29				2.33	29.60		
FR-P-474-302-96	MP	39.57	-77.19	02140304	Double Pipe Creek	SAM'S CR	3	14061		1.57				1.67		8.80	
FR-P-479-348-96	MP	39.64	-77.41	02140303	Upper Monocacy River	OWENS CR	3	8419		3.86				2.11			

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
FR-P-223-225-96	MP	82.51					4.71																7				0.00		PV	2				
FR-P-223-240-96	MP	83.64					5.44										9	8				10	8				0.00	PA	PA	7				
FR-P-258-202-96	MP																8	3					4	80			12.00	FR	CP	10				
FR-P-258-243-96	MP																	3				6	6				0.00		CP	6				
FR-P-261-122-96	MP	81.64					3.59										3	2	6								0.00		PA	3	5		18.00	
FR-P-263-311-96	MP						5.45		24.76									4									5.00	FR	PA	8				
FR-P-265-335-96	MP																											FR	FR					
FR-P-265-351-96	MP																											FR	FR					
FR-P-275-239-96	MP						3.38																10				0.00		PA	7				
FR-P-277-115-96	MP						4.09										9	3	7		8	5	7				0.00		CP	6			14.25	
FR-P-290-121-96	MP						4.57											1	7	5	2	3		100			0.00		PA				18.75	
FR-P-294-313-96	MP												X					1	7								2.00	FR	PA	2				
FR-P-294-357-96	MP																	9			9	7	9					FR	CP					
FR-P-298-308-96	MP																										3.00	FR	CP		9			
FR-P-300-130-96	MP	94.60					5.98		33.30								7	6	9	6	5	6	9	100			2.00	FR	CP				14.50	
FR-P-302-334-96	MP																					10					0.00		PA					
FR-P-319-352-96	MP																						10				0.00		PA	5				
FR-P-321-214-96	MP						4.08																5					FR	PA					
FR-P-335-110-96	MP						2.79		30.74								10	1	7		4			80			8.00	LN	PK	6	3			
FR-P-349-204-96	MP						4.16								X				9				5				0.00		SL	7				
FR-P-354-321-96	MP						6.13		25.17								10	2					4	80			11.00	FR	CP	10				
FR-P-371-132-96	MP	93.93					2.70		24.90								8	8	8		8	10	5			20	0.00		PA	6			14.00	
FR-P-377-242-96	MP						3.03															6	6					FR	CP		10			
FR-P-388-208-96	MP						2.83																6				0.00		PA	6				
FR-P-388-246-96	MP						3.12												9				8					FR	GR	5				
FR-P-394-317-96	MP						2.27		125.83													8	6			10	0.00		PA	8				
FR-P-399-126-96	MP						7.10										8		8			8	5				10.00	TG	PA				12.50	
FR-P-409-210-96	MP						3.85										7	3		7	7	9	8			10	0.00		CP					
FR-P-462-346-96	MP	85.34					6.16										9	8										OF	OF					
FR-P-474-302-96	MP	78.88					5.43		24.02														7				0.00		PA					
FR-P-479-348-96	MP												X									8					8.00	FR	PV	3	6			

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
FR-P-516-235-96	MP	39.56	-77.39	02140303	Upper Monocacy River	SANDY RUN	2	2209		3.29				2.78		6.71	
FR-P-545-325-96	MP	39.36	-77.31	02140302	Lower Monocacy River	BUSH CR	3	11917		4.43				2.78			
FR-P-545-345-96	MP	39.36	-77.31	02140302	Lower Monocacy River	BUSH CR	3	11942		4.43				1.67			
WA-B-017-232-96	MP	39.37	-77.67	02140301	Potomac River (Frederick County)	ISRAEL CR	2	3944						2.11		6.56	
WA-B-018-209-96	MP	39.34	-77.69	02140301	Potomac River (Frederick County)	ISRAEL CR	2	6995		3.00				2.56	5.56		
WA-B-018-241-96	MP	39.35	-77.68	02140301	Potomac River (Frederick County)	ISRAEL CR	2	6260		3.00				2.11	33.12	6.32	
AL-A-007-304-96	NO	39.70	-78.84	02141003	Wills Creek	NORTH BR OF JENNINGS RUN	3	8009		1.86				3.22	6.87		
AL-A-054-320-96	NO	39.52	-79.02	02141004	Georges Creek	GEORGES CR	3	38907		2.14				1.67	22.18		
AL-A-187-218-96	NO	39.48	-78.96	02141001	Potomac River (Lower North Branch)	DEEP HOLLOW	2	917		1.00				3.89	23.25		
AL-A-202-121-96	NO	39.60	-78.86	02141001	Potomac River (Lower North Branch)	WARRIOR RUN	1	1255		2.43				3.89			
AL-A-221-107-96	NO	39.52	-79.01	02141004	Georges Creek	GEORGES CR UT1	1	1216		1.00	1			2.33	20.79		
AL-A-229-109-96	NO	39.63	-78.98	02141004	Georges Creek	STAUB RUN	1	578		1.00	1			1.89	18.23		
AL-A-232-313-96	NO	39.65	-78.94	02141004	Georges Creek	SAND SPRING RUN	3	1903		1.86				1.89			
AL-A-254-326-96	NO	39.64	-78.85	02141003	Wills Creek	BRADDOCK RUN	3	6460		2.14		1		1.44			
AL-A-268-221-96	NO	39.56	-78.63	02141001	Potomac River (Lower North Branch)	SEVEN SPRINGS RUN	2	309		1.00				2.56	6.36		
AL-A-281-104-96	NO	39.46	-78.99	02141001	Potomac River (Lower North Branch)	DRY RUN	1	336						2.78			
AL-A-294-325-96	NO	39.56	-78.62	02141001	Potomac River (Lower North Branch)	TRADING RUN	3	5322		3.86				2.56	24.75		
AL-A-296-226-96	NO	39.71	-78.90	02141003	Wills Creek	JENNINGS RUN UT1	2	1337		1.00	1			1.67	17.33		
AL-A-343-307-96	NO	39.51	-79.04	02141004	Georges Creek	GEORGES CR	3	43960		1.29				1.67	30.90		
AL-A-343-330-96	NO	39.51	-79.04	02141004	Georges Creek	GEORGES CR	3	44197		2.14				2.56			
AL-A-380-303-96	NO	39.60	-78.65	02141001	Potomac River (Lower North Branch)	MILL RUN	3	3590		2.14				4.33			
AL-A-413-308-96	NO	39.64	-78.86	02141003	Wills Creek	BRADDOCK RUN	3	6081		2.14		1		1.44			
AL-A-425-314-96	NO	39.68	-78.71	02141002	Evitts Creek	ELK LICK RUN	3	3445		4.14				2.56			
AL-A-465-311-96	NO	39.59	-78.72	02141001	Potomac River (Lower North Branch)	COLLIER RUN	3	6298		2.71				4.56	28.34		
AL-A-465-324-96	NO	39.61	-78.70	02141001	Potomac River (Lower North Branch)	COLLIER RUN	3	5647		2.43				3.89	18.84		
AL-A-480-205-96	NO	39.63	-78.64	02141001	Potomac River (Lower North Branch)	MILL RUN	2	1105		1.29				3.67			
AL-A-485-220-96	NO	39.59	-78.85	02141001	Potomac River (Lower North Branch)	POTOMAC R UT2	2	801		1.00				3.22	23.99		
AL-A-485-227-96	NO	39.58	-78.85	02141001	Potomac River (Lower North Branch)	POTOMAC R UT2	2	1124		1.00				1.44	14.84		
AL-A-567-126-96	NO	39.67	-78.95	02141004	Georges Creek	SAND SPRING RUN UT1	1	161			1			1.67	8.15		
AL-A-585-122-96	NO	39.58	-78.83	02141001	Potomac River (Lower North Branch)	POTOMAC R UT3	1	383		1.29				3.22	30.03		
AL-A-626-216-96	NO	39.55	-78.91	02141001	Potomac River (Lower North Branch)	MILL RUN	2	498		2.71		1		3.67			

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
FR-P-516-235-96	MP																	1					5			25	0.00		PA	6				
FR-P-545-325-96	MP						2.89															8	10				5.00	FR	DI					
FR-P-545-345-96	MP						2.92																10				10.00	FR	DI					
WA-B-017-232-96	MP						3.25																											
WA-B-018-209-96	MP						2.41						X				9	1	8		3							FR	PA		10			
WA-B-018-241-96	MP						2.41															8					2.00	FR	PA	2	2			
AL-A-007-304-96	NO								73.51									7	9	9	5			100				LN	HO	2				
AL-A-054-320-96	NO								235.87				X					5			5	4					0.00		RR	1	2			
AL-A-187-218-96	NO																9	5			7	10						FR	FR				18.50	
AL-A-202-121-96	NO								44.96										10								0.00		PA					
AL-A-221-107-96	NO		4.98	3.95	-3.40	AMD			520.27									2	10			9	9					FR	LN	6	3		12.25	
AL-A-229-109-96	NO			4.72	-10.50	AD												8	8	9	9							FR	FR				11.25	
AL-A-232-313-96	NO				175.70	AMD & AD							X					10									0.00		LN	1	5			
AL-A-254-326-96	NO								346.43				X					3				5					0.00		PK	1	1			
AL-A-268-221-96	NO								28.98								9		8	8	7			100			2.00	FR	OF				9.75	
AL-A-281-104-96	NO				119.80	AMD			31.19																									
AL-A-294-325-96	NO								24.63									5			8		9				0.00		PA	6	7			
AL-A-296-226-96	NO		4.14	4.76	-92.20	AMD			128.98									1			5							FR	LN	6	5		12.00	
AL-A-343-307-96	NO								263.14				X											80		25	11.00	FR	RR	6	1			
AL-A-343-330-96	NO								349.54				X					10				1				15	0.00		PV	0	2			
AL-A-380-303-96	NO								26.48										10			10					7.00	FR	PA	5			18.50	
AL-A-413-308-96	NO								296.74				X					3			2							FR	TG	7	5			
AL-A-425-314-96	NO								49.25				X					4			7						13.00	FR	PV	2	9			
AL-A-465-311-96	NO																		10					100			0.00		PA	5	10			
AL-A-465-324-96	NO																		8	10	10	9		100				FR	FR					
AL-A-480-205-96	NO																					6						FR	FR				14.25	
AL-A-485-220-96	NO				140.60	AD															10							FR	FR		6		9.50	
AL-A-485-227-96	NO												X	X					7	7		1					0.00		PK	1	2		12.75	
AL-A-567-126-96	NO		4.57	4.85	-12.70	AMD			25.54								9	1			4	1						FR	FR		5		13.50	
AL-A-585-122-96	NO						2.46		37.01									5	9		10							FR	FR				19.50	
AL-A-626-216-96	NO																	10						100				FR	FR				12.75	

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
AL-A-706-228-96	NO	39.66	-78.66	02141001	Potomac River (Lower North Branch)	COLLIER RUN	2	962		1.29				3.89	18.53		
AL-A-999-117-96	NO	39.71	-78.77	02141003	Wills Creek	WILLS CR UT1	1	440		1.00	1			3.89	11.36		
GA-A-017-223-96	NO	39.36	-79.29	02141005	Potomac River (Upper North Branch)	LAUREL RUN	2	1827		1.57		1		2.78			
GA-A-133-112-96	NO	39.49	-79.18	02141006	Savage River	SPRING LICK	1	990		2.43		1		3.67	39.26		
GA-A-191-322-96	NO	39.34	-79.26	02141005	Potomac River (Upper North Branch)	LAUREL RUN	3	5496		3.86				2.56	15.91		
GA-A-205-222-96	NO	39.41	-79.17	02141005	Potomac River (Upper North Branch)	THREE FORKS RUN	2	5923		1.00	1			1.44	8.30		
GA-A-470-306-96	NO	39.36	-79.24	02141005	Potomac River (Upper North Branch)	LOSTLAND RUN	3	6499		2.43		1		2.56			
GA-A-470-309-96	NO	39.36	-79.24	02141005	Potomac River (Upper North Branch)	LOSTLAND RUN	3	6565		1.86		1		2.11	25.13		
GA-A-470-315-96	NO	39.36	-79.23	02141005	Potomac River (Upper North Branch)	LOSTLAND RUN	3	6574		3.00		1		2.33			
GA-A-496-105-96	NO	39.33	-79.35	02141005	Potomac River (Upper North Branch)	GLADE RUN	1	310		2.43				2.78	3.76	6.07	
GA-A-523-203-96	NO	39.48	-79.12	02141005	Potomac River (Upper North Branch)	LAUREL RUN UT1	2	1543		2.43		1		4.56			
GA-A-558-211-96	NO	39.66	-79.00	02141006	Savage River	SAVAGE R	2	3764		4.14		1		2.33			
CN-N-031-122-95	NW	38.80	-75.75	02130306	Marshyhope Creek	TOMMY WRIGHT BR	1	2046.19		3.75				1.86	33.97		
DO-S-006-101-95	NW	38.68	-75.83	02130306	Marshyhope Creek	SKINNER RUN	1	1288.86		3.25			1	2.71	8.79		
DO-S-029-103-95	NW	38.55	-75.95	02130308	Transquaking River	HIGGINS MILLPOND	1	4291.02		3.00				1.29	26.13	7.46	
SO-S-005-109-95	NW	38.30	-75.66	02130303	Wicomico Creek	PASSERDYKE CR	1	4870.35		2.25				1.86	5.90	6.41	
WI-S-016-211-95	NW	38.36	-75.58	02130301	Lower Wicomico River	BEAVERDAM CR	2	13550.87		2.50				2.43	26.35		
WI-S-017-119-95	NW	38.34	-75.52	02130301	Lower Wicomico River	WALSTON BR	1	999.92		2.25				1.57	11.27	7.58	
WI-S-073-114-95	NW	38.38	-75.62	02130301	Lower Wicomico River	OWENS BR	1	1054.8		3.25				2.71	1.79		
WI-S-085-102-95	NW	38.43	-75.78	02130305	Nanticoke River	INGEM GUT	1	470.73		1.75			1	2.14	8.11	6.60	
SO-S-003-111-97	PC	38.16	-75.65	02130208	Manokin River	KINGS CR	1	6975.61		3.25			1	1.86	18.38	6.56	
SO-S-004-109-97	PC	38.12	-75.64	02130201	Pocomoke Sound	MARUMSCO CR	1	77.95						1.00		7.79	
SO-S-004-113-97	PC	38.08	-75.69	02130201	Pocomoke Sound	MARUMSCO CR	1	3766.77		2.00			1	2.14	15.16	6.00	
WI-S-019-217-97	PC	38.43	-75.37	02130203	Upper Pocomoke River	GREEN RUN	2	4572.27		3.25			1	2.71	31.07	7.02	
WI-S-037-210-97	PC	38.40	-75.34	02130203	Upper Pocomoke River	BURNT MILL BR	2	11721.44		3.00				2.71	21.92	6.79	
WI-S-041-202-97	PC	38.39	-75.48	02130301	Lower Wicomico River	PERDUE CR	2	107.24						1.86		6.91	42.20
WI-S-041-214-97	PC	38.35	-75.46	02130205	Nassawango Creek	FOREST GROVE BR	2	1570.8	45.00	3.25				1.57	41.73	6.87	
WI-S-055-303-97	PC	38.33	-75.33	02130203	Upper Pocomoke River	POCOMOKE R	3	71830.65		3.00				1.29			
WI-S-059-106-97	PC	38.35	-75.37	02130203	Upper Pocomoke River	TRUITT BR	1	1245.28		2.25				2.14	1.27		
WI-S-061-104-97	PC	38.43	-75.44	02130203	Upper Pocomoke River	BURNT MILL BR	1	494.54						1.57		6.85	
WI-S-067-207-97	PC	38.40	-75.37	02130203	Upper Pocomoke River	BURNT MILL BR	2	9189.98		3.75				2.71		6.34	

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
AL-A-706-228-96	NO				30.60	AD												5	6			10						FR	FR				19.50	
AL-A-999-117-96	NO						2.76		42.97								6		8	7	7						0.00		GR	5		16.00	6.25	
GA-A-017-223-96	NO				132.00	AMD			41.20		X							5									0.00		TG					
GA-A-133-112-96	NO				149.00	AD							X						10		9	10					0.00		DI	7			11.00	
GA-A-191-322-96	NO								58.88				X				8	6						100			5.00	FR	DI	5				
GA-A-205-222-96	NO		3.62	3.36	-319.70	AMD			160.58				X					0			2			100				FR	GR	9	1			
GA-A-470-306-96	NO				187.90	AMD			62.81									8						100				FR	FR					
GA-A-470-309-96	NO				185.10	AMD			61.64									6			5			100				FR	FR					
GA-A-470-315-96	NO				177.80	AMD			61.14									10										FR	FR	8				
GA-A-496-105-96	NO								67.06								4	2	7	10	6	6	5				0.00		CP	6			11.25	
GA-A-523-203-96	NO								63.18																			FR	FR					
GA-A-558-211-96	NO				183.20	AMD & AD												3				10						FR	FR					
CN-N-031-122-95	NW						6.10						X				10	5	6		0	2		100	10	10		OF	FR					
DO-S-006-101-95	NW				166.81	AGR	3.39			16.00			X				6	5	4	8	6	4		100				FR	OF	6	4			
DO-S-029-103-95	NW						16.16	4.20	33.91	10.00							7	3	6		4	4		100				FR	CP	5				
SO-S-005-109-95	NW								25.01	8.00			X				5	1	7	3		5	6	100		20	10.00	OF	CP	7	7		17.00	
WI-S-016-211-95	NW						2.83						X				5	3	6		0	4		100		10	4.00	LN	PK	2	8			
WI-S-017-119-95	NW												X				6	4	6	6	10	5	9	100				FR	CP	6	7			
WI-S-073-114-95	NW						5.69										3	1	2	1	4	4	10	100				LN	PV	3	3		11.00	
WI-S-085-102-95	NW		4.99		17.51	ORG & AD		4.00	28.60	10.00			X				5	1	3	7	0	4		100				LO	LO	9				
SO-S-003-111-97	PC		4.99		22.70	ORG & AD				24.00			X				8	5	6	7	4	10		99				FR	FR	10				
SO-S-004-109-97	PC		4.87		19.70	ORG				27.60																								
SO-S-004-113-97	PC				158.90	ORG & AD				15.80			X				5	5	6	8	3	5	10	100				FR	FR				19.25	
WI-S-019-217-97	PC				180.60	AGR	5.21			10.40			X					10	8	10		5		100		20	3.00	OF	CP	4	10			
WI-S-037-210-97	PC						4.53			11.10			X				5	3	6			5		100		10	0.00		CP	4				
WI-S-041-202-97	PC						4.05			13.20																								
WI-S-041-214-97	PC							1.00		14.60			X						4		0	6		100				FR	PA	5			14.75	
WI-S-055-303-97	PC						2.87			11.70			X					10	8			5	10	100				FR	FR	9				
WI-S-059-106-97	PC						4.82			25.60			X				1	1	2	2	3	0	1	100			0.00		CP	1	1	10.00	6.75	BC
WI-S-061-104-97	PC				78.90	AGR	3.05			10.00																								
WI-S-067-207-97	PC						4.05			9.10			X				10	9	10			9	8	100		10	10.00	OF	FR	10				

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
WI-S-067-219-97	PC	38.40	-75.36	02130203	Upper Pocomoke River	BURNT MILL BR	2	10352.87		3.75				1.57		7.75	
WI-S-074-103-97	PC	38.40	-75.35	02130203	Upper Pocomoke River	MURRAY BR	1	694.16		3.75				1.86		7.75	
WI-S-084-107-97	PC	38.38	-75.43	02130203	Upper Pocomoke River	CAMPBELL DITCH	1	1444.27		2.25			1	1.00	2.76	7.15	
WI-S-999-114-97	PC	38.30	-75.37	02130203	Upper Pocomoke River	DUNCAN DITCH	1	1912.07		2.75			1	1.57	14.33		
WO-S-003-308-97	PC	38.40	-75.32	02130203	Upper Pocomoke River	POCOMOKE R	3	35917.29		2.75			1	3.57	24.67		
WO-S-004-110-97	PC	38.09	-75.46	02130202	Lower Pocomoke River	JONES DITCH	1	2020.32		4.25				1.86		6.12	
WO-S-038-108-97	PC	38.25	-75.49	02130205	Nassawango Creek	MILLVILLE CR	1	3574.24		3.25			1	1.29		7.28	
WO-S-038-115-97	PC	38.27	-75.51	02130205	Nassawango Creek	MILLVILLE CR	1	359.26						1.29		7.38	
WO-S-061-205-97	PC	38.43	-75.33	02130203	Upper Pocomoke River	NORTH FORK GREEN RUN	2	8933.33						1.86			
WO-S-061-206-97	PC	38.44	-75.35	02130203	Upper Pocomoke River	NORTH FORK GREEN RUN	2	8137.92		3.75				2.43		6.57	
WO-S-999-229-97	PC	38.01	-75.54	02130202	Lower Pocomoke River	WAGRAM CR	2	6083.66						2.14		7.48	
AA-N-020-124-96	PP	39.15	-76.56	02130903	Baltimore Harbor	SLOOP COVE UT1	1	162			1			1.57	13.03		
AA-N-104-114-95	PP	39.13	-76.63	02130903	Baltimore Harbor	MARLEY CR UT1	1	309.76		2.00				1.57	19.56		67.00
AA-N-126-306-95	PP	39.18	-76.62	02130903	Baltimore Harbor	SAWMILL CR	3	5224.04		3.00				2.43			45.79
AA-N-180-130-95	PP	39.14	-76.71	02130906	Patapsco River Lower North Branch	STONY RUN	1	335.32	73.00	3.25				2.71	13.15		25.57
AA-N-244-203-95	PP	39.18	-76.63	02130903	Baltimore Harbor	SAWMILL RUN UT2	2	577.93		2.50				2.43		6.31	75.65
AA-N-262-101-96	PP	39.15	-76.61	02130903	Baltimore Harbor	MARLEY CR	1	832		1.00	1			1.00	1.61		89.90
AA-N-323-225-96	PP	39.16	-76.65	02130903	Baltimore Harbor	SAWMILL CR	2	1546		3.25				2.71		6.75	
BA-N-001-211-96	PP	39.35	-76.50	02130901	Back River	STEMMERS RUN	2	2425		1.67				1.00			60.41
BA-N-011-307-95	PP	39.22	-76.69	02130906	Patapsco River Lower North Branch	HERBERT RUN	3	4167.36		3.75				1.57			65.14
BA-N-019-301-95	PP	39.25	-76.70	02130906	Patapsco River Lower North Branch	WEST BR HERBERT RUN	3	1827.38		2.33				3.00			52.56
BA-N-019-308-95	PP	39.25	-76.70	02130906	Patapsco River Lower North Branch	WEST BR	3	1961.41		1.67				1.57			52.63
BA-N-045-223-96	PP	39.30	-76.53	02130901	Back River	MOORE'S RUN	2	11859		3.25				1.00			76.36
BA-N-047-128-96	PP	39.34	-76.51	02130901	Back River	REDHOUSE RUN	1	957		1.22				1.29			73.88
BA-N-057-113-96	PP	39.23	-76.67	02130906	Patapsco River Lower North Branch	PATAPSCO R UT1	1	620		1.00	1			1.00	20.81		72.42
BA-N-065-215-96	PP	39.37	-76.52	02130901	Back River	STEMMERS RUN	2	1177		2.56				1.00			62.02
BA-P-002-303-96	PP	39.41	-76.71	02130904	Jones Falls	JONES FLS	3	7862		2.56				3.00			
BA-P-002-319-95	PP	39.41	-76.71	02130904	Jones Falls	JONES FLS	3	7816.36		2.56				2.78			
BA-P-013-328-96	PP	39.31	-76.73	02130905	Gwynns Falls	DEAD RUN	3	2758		1.44				1.67			82.02
BA-P-074-106-96	PP	39.40	-76.63	02130904	Jones Falls	TOWSON RUN UT1	1	339		1.00				2.11	6.87		72.27
BA-P-077-322-95	PP	39.43	-76.73	02130904	Jones Falls	N BRANCH JONES FLS	3	3114.59	73.00	2.56				3.44			

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
WI-S-067-219-97	PC						2.56			9.70			X		X		10	6				5		100		20	0.00		LN	5				
WI-S-074-103-97	PC						4.29			10.70			X				10	5		10		2		100		25		OF	FR	10				
WI-S-084-107-97	PC		4.57		-26.90	ORG & AD		3.40		10.90			X				4	3	2	2	0	5		100			0.00		CP	5	5		18.25	
WI-S-999-114-97	PC				124.00	AGR	5.41			10.60			X				6	5	5	6	8	5		100				FR	CP				18.75	
WO-S-003-308-97	PC				134.50	AGR	3.32			12.30			X						5	6	6	5	10	100			3.00	FR	DI	10				
WO-S-004-110-97	PC							3.50		15.10									9		8	10		100				FR	CP					
WO-S-038-108-97	PC		4.40	4.40	-64.60	ORG		1.50		32.90									2		0			100				FR	LO		10			
WO-S-038-115-97	PC		4.91		9.40	ORG & AD				12.90																								
WO-S-061-205-97	PC						4.01			8.40																								
WO-S-061-206-97	PC						4.73			8.10			X						6		0			100		20	3.00	OF	CP	6				
WO-S-999-229-97	PC								31.75	12.50																								
AA-N-020-124-96	PP				55.90	AD												1	3	9	2	4	9	100			0.00		SL	6	1			
AA-N-104-114-95	PP																6	4	6		8	7	7	80				FR	HO	6	6		12.00	
AA-N-126-306-95	PP													X				10			5		10				0.00		HO	5				
AA-N-180-130-95	PP						3.62		29.90				X				5	5	8	6		4		80			0.00		CP	5	6		17.00	
AA-N-244-203-95	PP						3.11		26.89					X				7				5	5				0.00		HO	2	3		15.75	
AA-N-262-101-96	PP									14.60			X				0	0	6	1	2	2		100	20	20	0.00		HO	0	1	12.00	5.25	
AA-N-323-225-96	PP								25.47															85				FR	FR	10				
BA-N-001-211-96	PP									8.30			X	X			9	9	10		2						0.00		PV	3	4			
BA-N-011-307-95	PP								38.58					X			10	9			10	5	5				0.00		PV	2	6			
BA-N-019-301-95	PP								38.30													10	7				0.00		PV	1	4		11.75	
BA-N-019-308-95	PP								39.93				X	X								2					0.00		HO	1	2		16.75	
BA-N-045-223-96	PP												X	X	X		8					1	5		20		0.00		PV	1	2			
BA-N-047-128-96	PP									14.40			X	X				10	8		5		8	80			0.00		PV	2	2			
BA-N-057-113-96	PP							1.00	35.86	8.20								5	3		0	7	5	98			0.00		RR	4	2		8.00	
BA-N-065-215-96	PP								28.48													9	6				0.00		LN	5	9			
BA-P-002-303-96	PP													X								6	10				0.00		PA	6				
BA-P-002-319-95	PP																9						10				0.00		LN	5	8			
BA-P-013-328-96	PP						2.13						X										10					FR	PV	6	6			
BA-P-074-106-96	PP								33.24				X				7		8	7	10	6		80			0.00		PV	1	8		9.50	
BA-P-077-322-95	PP																		10				10					FR	PV				15.25	

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
BA-P-125-126-96	PP	39.36	-76.76	02130905	Gwynns Falls	SCOTTS LEVEL BR	1	2109		2.56				1.44	6.36		66.57
BA-P-145-316-96	PP	39.38	-76.76	02130905	Gwynns Falls	GWYNNS FLS	3	13869		2.33				2.33			
BA-P-145-327-96	PP	39.39	-76.76	02130905	Gwynns Falls	GWYNNS FLS	3	13842		3.22				2.11			
BA-P-262-111-96	PP	39.32	-76.73	02130905	Gwynns Falls	GWYNNS FLS UT1	1	148			1			1.89	5.45		66.22
BA-P-269-214-96	PP	39.38	-76.69	02130904	Jones Falls	MOORE'S BR	2	789		1.00	1			1.22			52.47
BA-P-331-315-95	PP	39.34	-76.73	02130905	Gwynns Falls	GWYNNS FLS	3	20974.82		2.78				1.44			35.10
BA-P-409-102-96	PP	39.45	-76.83	02130905	Gwynns Falls	RED RUN	1	77			1			2.56	5.15		
BA-P-410-203-96	PP	39.44	-76.78	02130905	Gwynns Falls	GWYNNS FLS	2	3122		3.00				1.44			28.44
BA-P-415-119-95	PP	39.27	-76.79	02130906	Patapsco River Lower North Branch	COOPER BR	1	521.77		1.00				2.11			34.36
BA-P-464-117-95	PP	39.26	-76.71	02130906	Patapsco River Lower North Branch	HERBERT RUN	1	501.98		1.00				1.89		6.36	57.75
BA-P-478-314-96	PP	39.35	-76.74	02130905	Gwynns Falls	GWYNNS FLS	3	19380		2.11				2.33			31.80
BA-P-478-325-95	PP	39.36	-76.74	02130905	Gwynns Falls	GWYNNS FLS	3	19299.69		2.78				1.67			31.76
BC-N-012-120-96	PP	39.32	-76.63	02130904	Jones Falls	STONY RUN	1	2869		1.00	1			1.00			74.94
BC-N-014-216-95	PP	39.32	-76.53	02130901	Back River	MOORES RUN	2	2756.25		2.50				1.29		6.88	85.23
BC-N-014-217-96	PP	39.33	-76.54	02130901	Back River	MOORE'S RUN	2	1943		1.67				1.00			88.57
BC-N-014-224-95	PP	39.32	-76.53	02130901	Back River	MOORE'S RUN	2	2756.85		3.00				1.86			85.28
BC-N-015-202-96	PP	39.33	-76.57	02130901	Back River	HERRING RUN	2	8464		1.22				1.00	32.03		77.28
BC-N-015-219-95	PP	39.33	-76.57	02130901	Back River	HERRING RUN	2	8820.26		2.56				1.29		6.43	76.49
BC-P-001-326-96	PP	39.31	-76.69	02130905	Gwynns Falls	GWYNNS FLS	3	26594		2.56				1.22			41.49
BC-P-003-205-95	PP	39.36	-76.57	02130901	Back River	TRIB TO HERRING RUN	2	2669.24		1.89				1.22	38.77	6.77	79.74
BC-P-003-228-96	PP	39.36	-76.57	02130901	Back River	HERRING RUN	2	2758		1.22				1.00			80.02
BC-P-004-107-96	PP	39.35	-76.59	02130901	Back River	CHINQUAPIN RUN	1	1416	51.00	1.00	1			1.44	0.31	9.78	86.86
BC-P-005-306-96	PP	39.30	-76.70	02130905	Gwynns Falls	DEAD RUN	3	4659		1.67				2.33			74.89
BC-P-005-318-96	PP	39.30	-76.71	02130905	Gwynns Falls	DEAD RUN	3	4145		1.67				1.44			78.29
CR-P-020-208-96	PP	39.41	-76.92	02130907	Liberty Reservoir	LIBERTY RES UT1	2	1318		3.89				1.67		6.41	
CR-P-038-227-95	PP	39.58	-76.98	02130907	Liberty Reservoir	W BR PATAPSCO R	2	3818.93		2.78				2.11			
CR-P-050-106-95	PP	39.54	-76.94	02130907	Liberty Reservoir	BEAVER RUN UT1	1	331.85		2.78				4.11			
CR-P-079-209-96	PP	39.47	-76.91	02130907	Liberty Reservoir	MIDDLE RUN	2	3762		4.78				2.78			
CR-P-086-313-96	PP	39.37	-77.08	02130908	South Branch Patapsco	GILLIS FLS	3	12157		4.56				2.11		6.06	
CR-P-086-325-96	PP	39.37	-77.08	02130908	South Branch Patapsco	GILLIS FLS	3	11701		3.89				1.44		6.76	
CR-P-120-232-96	PP	39.36	-77.07	02130908	South Branch Patapsco	PATAPSCO R	2	7320		4.56				2.33		6.16	

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
BA-P-125-126-96	PP												X					7	9		4	5	7	90			3.00	LN	PV	2	6			DM
BA-P-145-316-96	PP						2.03						X					10				7	7					FR	FR		10			
BA-P-145-327-96	PP						2.13																10					FR	FR					
BA-P-262-111-96	PP								29.01				X	X					5		8	6	7	80			0.00		PV	1	2		14.00	
BA-P-269-214-96	PP						3.20		78.58				X														0.00		DI	4	2			
BA-P-331-315-95	PP																						8					OF	HO	7	8			
BA-P-409-102-96	PP	84.42			162.10	AGR	5.89										4	4	4	7	6		9				8.00	FR	CP			18.00	7.50	
BA-P-410-203-96	PP						2.26																8				8.00	FR	RR	9				
BA-P-415-119-95	PP								39.60																			FR	HO	5	6		18.50	
BA-P-464-117-95	PP								45.82					X								9	5				0.00		LN	3	3			
BA-P-478-314-96	PP						2.04						X					8	9		5		5	95			1.00	OF	LN		5			
BA-P-478-325-95	PP																				6							FR	PV	8	6			
BC-N-012-120-96	PP																10					7	10				0.00		PV	6	1		18.75	DM
BC-N-014-216-95	PP							4.40	40.67				X				10	8	8		4	6	10				0.00		PV	0	2			
BC-N-014-217-96	PP									8.80			X	X									10				0.00		LN	2	2		18.00	
BC-N-014-224-95	PP								38.54				X					4	7		0		8				0.00		PV	1	2			
BC-N-015-202-96	PP																		8	6		6					0.00		LN	6	2			
BC-N-015-219-95	PP													X								5	6				0.00		PV	3	6			
BC-P-001-326-96	PP												X									10					0.00		PV	6	5			
BC-P-003-205-95	PP						2.64		27.16				X	X					8			5					0.00		PV	0	5			
BC-P-003-228-96	PP												X	X								2					0.00		LN	3	1			DM
BC-P-004-107-96	PP						2.42	0.90					X	X			3	2	1		0	5	5	100	10		0.00		PV	0	0		12.00	DM
BC-P-005-306-96	PP								45.64				X										8			15		FR	PV	8	8			
BC-P-005-318-96	PP								44.93				X	X													0.00		LN	4	8			
CR-P-020-208-96	PP						2.58															10	9				0.00		LN	6	10			
CR-P-038-227-95	PP	78.70					6.28						X				10					8	10				10.00	FR	PV	2	6			
CR-P-050-106-95	PP	90.02					9.07												8	8	10	8	8					FR	TG	10			18.50	
CR-P-079-209-96	PP	83.17					4.05																7				0.00		PA					
CR-P-086-313-96	PP						3.86																					OF	FR					
CR-P-086-325-96	PP						4.11															8	3				0.00		LN	9				
CR-P-120-232-96	PP						3.90																4				0.00		LN	6				

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
CR-P-152-302-96	PP	39.50	-76.88	02130907	Liberty Reservoir	NORTH BR PATAPSCO R	3	36181						2.56		6.34	
CR-P-152-318-95	PP	39.50	-76.88	02130907	Liberty Reservoir	N BR PATAPSCO R	3	32298.53		3.67				2.78			
CR-P-193-311-96	PP	39.49	-76.90	02130907	Liberty Reservoir	BEAVER RUN	3	8260		4.11				2.78			
CR-P-215-127-96	PP	39.47	-76.90	02130907	Liberty Reservoir	LIBERTY RES UT2	1	301		3.89				2.33			
CR-P-242-224-96	PP	39.55	-76.89	02130907	Liberty Reservoir	EAST BR PATAPSCO	2	13000		3.89				2.11			
CR-P-260-210-96	PP	39.54	-76.96	02130907	Liberty Reservoir	BEAVER RUN	2	1693		4.56				2.56	34.04		
CR-P-281-127-95	PP	39.36	-77.12	02130908	South Branch Patapsco	PATAPSCO R UT2	1	722.44		4.33				2.78	39.26	6.83	
CR-P-330-229-96	PP	39.59	-76.89	02130907	Liberty Reservoir	EAST BR PATAPSCO	2	6318		4.78				2.56			
CR-P-345-321-96	PP	39.45	-76.96	02130907	Liberty Reservoir	MORGAN RUN	3	17770		4.11				2.11		6.15	
CR-P-363-212-96	PP	39.38	-76.95	02130908	South Branch Patapsco	PINEY RUN	2	7807		4.56				1.89			
CR-P-376-104-96	PP	39.39	-76.95	02130908	South Branch Patapsco	PINEY RUN UT1	1	505		3.00				2.56			
CR-P-379-123-96	PP	39.53	-77.03	02130907	Liberty Reservoir	MORGAN RUN	1	141						1.67	8.62	6.03	
CR-P-419-214-95	PP	39.39	-77.08	02130908	South Branch Patapsco	GILLIS FLS	2	6423.15		4.33				2.56		6.13	
CR-P-419-227-96	PP	39.40	-77.08	02130908	South Branch Patapsco	GILLIS FLS	2	6171		3.89				1.67		6.71	
CR-P-999-323-95	PP	39.52	-76.93	02130907	Liberty Reservoir	BEAVER RUN	3	6105.85		3.89				2.56			
HO-N-001-210-95	PP	39.19	-76.72	02130906	Patapsco River Lower North Branch	DEEP RUN	2	3204.35		4.50				1.57			29.66
HO-N-018-213-95	PP	39.18	-76.75	02130906	Patapsco River Lower North Branch	DEEP RUN	2	2754.74		3.44				1.57			28.79
HO-N-019-304-96	PP	39.20	-76.71	02130906	Patapsco River Lower North Branch	DEEP RUN	3	12109		3.25				2.71			
HO-N-026-305-95	PP	39.18	-76.74	02130906	Patapsco River Lower North Branch	DEEP RUN	3	4944.79		4.25				2.43		6.32	
HO-P-068-231-96	PP	39.22	-76.74	02130906	Patapsco River Lower North Branch	ROCKBURN BR	2	1893		3.67				1.00			
HO-P-094-116-96	PP	39.35	-77.11	02130908	South Branch Patapsco	HAY MEADOW BR UT1	1	639		3.67				2.56	22.89		
HO-P-244-307-96	PP	39.35	-77.04	02130908	South Branch Patapsco	PATAPSCO R	3	22377						2.11			
MO-P-001-214-97	PW	39.09	-77.17	02140202	Potomac River (Montgomery County)	WATTS BR	2	1495.54		2.14				2.11			37.36
MO-P-014-107-97	PW	39.16	-77.52	02140202	Potomac River (Montgomery County)	POTOMAC R UT7	1	379.47		2.14				2.78	17.92	7.27	
MO-P-016-227-97	PW	39.15	-77.44	02140202	Potomac River (Montgomery County)	BROAD RUN	2	1396.23		2.71				2.78	22.18		
MO-P-024-315-97	PW	39.20	-77.27	02140208	Seneca Creek	LITTLE SENECA CR	3	4462.26		1.86				3.89	37.81		
MO-P-056-319-97	PW	39.06	-77.02	02140205	Anacostia River	NORTHWEST BR ANACOSTIA R	3	14466.82		3.89				1.67		9.34	
MO-P-082-124-97	PW	39.05	-77.14	02140207	Cabin John Creek	OLD FARM CR	1	484.3		1.67				1.67		6.32	49.32
MO-P-091-204-97	PW	39.11	-77.23	02140202	Potomac River (Montgomery County)	MUDDY BR	2	4266.05		2.71				2.56		6.00	38.27
MO-P-101-126-97	PW	39.07	-77.08	02140206	Rock Creek	TURKEY BR	1	498.28		1.44				1.44		8.75	80.78
MO-P-102-308-97	PW	39.09	-77.35	02140208	Seneca Creek	DRY SENECA CR	3	4311.14		4.43				2.56		6.76	
MO-P-108-123-97	PW	39.09	-77.18	02140202	Potomac River (Montgomery County)	WATTS BR UT1	1	509.87		2.71				1.67	41.23	6.83	51.52

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
CR-P-152-302-96	PP						4.76																											
CR-P-152-318-95	PP						4.60								X								7				0.00		PV	3	10			GW
CR-P-193-311-96	PP						4.45						X														0.00		PV	0				
CR-P-215-127-96	PP						4.76															10	10					FR	FR					
CR-P-242-224-96	PP	78.48					5.74																10				0.00		LN	6				
CR-P-260-210-96	PP						5.62											10	10			9	5					OF	PV	5				
CR-P-281-127-95	PP						4.95																5					FR	FR				15.75	
CR-P-330-229-96	PP	83.89					6.50																			20	0.00		PA	3	7			
CR-P-345-321-96	PP						4.02																				0.00		DI	7				
CR-P-363-212-96	PP																	9				10						OF	OF	10				
CR-P-376-104-96	PP	78.81					3.26																				6.00	OF	LN	7	10			
CR-P-379-123-96	PP	90.78					9.01						X				6	6			8			80			0.00		CP	7			9.75	
CR-P-419-214-95	PP						4.47																				0.00		PA					
CR-P-419-227-96	PP						4.49															9	7				14.00	FR	OF					
CR-P-999-323-95	PP						4.81																10					FR	FR	10				
HO-N-001-210-95	PP								24.51														10				0.00		PK		10			
HO-N-018-213-95	PP								27.58														5					FR	HO	8				
HO-N-019-304-96	PP								24.36								6	5	8		0	5	4	100				FR	FR	10	6			
HO-N-026-305-95	PP																7	8				6	7					FR	PV					
HO-P-068-231-96	PP																		10				10					FR	FR					
HO-P-094-116-96	PP	81.69					3.53												8	10			4					FR	PA	9	6			
HO-P-244-307-96	PP						4.05																											
MO-P-001-214-97	PW						4.05							X													0.00		LN	0	10			
MO-P-014-107-97	PW																10	5			3	5					0.00		SL	1			17.00	
MO-P-016-227-97	PW															X			10	10	6	6						FR	FR					
MO-P-024-315-97	PW	75.81					3.79						X		X	X		5	10		0	5	10				0.00		PV	7				
MO-P-056-319-97	PW																	6				5	5				0.00		FR	10				
MO-P-082-124-97	PW																				7	9	10					FR	LN	4				
MO-P-091-204-97	PW						2.05															8	7					FR	HO	10				
MO-P-101-126-97	PW								40.04													7						FR	FR	2	8			
MO-P-102-308-97	PW						2.47																				5.00	FR	PV	3				
MO-P-108-123-97	PW						5.25						X		X						8	4					0.00		PK	1				

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
MO-P-108-123-97	PW	39.09	-77.18	02140202	Potomac River (Montgomery County)	WATTS BR UT1	1	509.87		2.71				1.67	41.23	6.83	51.52
MO-P-129-114-97	PW	39.16	-77.30	02140208	Seneca Creek	SENECA CR UT2	1	80.46						1.67	18.53	6.73	
MO-P-129-131-97	PW	39.16	-77.31	02140208	Seneca Creek	SENECA CR UT2	1	268.38						2.56	28.75		
MO-P-153-113-97	PW	39.16	-77.13	02140206	Rock Creek	ROCK CR UT1	1	574.52		4.33				2.78			
MO-P-159-110-97	PW	39.18	-77.24	02140208	Seneca Creek	GUNNERS BR	1	219.51						2.56	13.12		27.59
MO-P-182-325-97	PW	39.01	-77.17	02140207	Cabin John Creek	CABIN JOHN CR	3	8611.67		3.00				2.56		6.61	47.13
MO-P-258-213-97	PW	39.09	-76.93	02140205	Anacostia River	LITTLE PAINT BR	2	739.08		2.78				2.78		6.99	26.47
MO-P-269-203-97	PW	39.00	-77.01	02140205	Anacostia River	SLIGO CR	2	3398.22		1.44				1.67			65.57
MO-P-304-127-97	PW	39.10	-77.01	02140205	Anacostia River	NORTHWEST BR UT1	1	248.84						2.56	32.67		64.26
MO-P-308-117-97	PW	39.13	-77.16	02140206	Rock Creek	MILL CR UT1	1	377.13		1.22				1.67	29.60	9.24	48.72
MO-P-310-313-97	PW	39.10	-77.13	02140206	Rock Creek	ROCK CR	3	10606.55		2.78				1.00		7.61	
MO-P-316-205-97	PW	39.13	-77.15	02140206	Rock Creek	MILL CR	2	1096.69		1.67				2.56		7.97	49.17
MO-P-436-226-97	PW	39.08	-77.39	02140202	Potomac River (Montgomery County)	POTOMAC R UT8	2	1126.73		1.29				2.56	6.01		
MO-P-437-206-97	PW	39.14	-77.13	02140206	Rock Creek	ROCK CR	2	4748.66		4.11				2.78			
MO-P-468-109-97	PW	39.28	-77.21	02140208	Seneca Creek	MAGRUDER BR	1	160.19						1.67	40.24	7.69	
MO-P-474-317-97	PW	39.15	-77.34	02140208	Seneca Creek	SENECA CR	3	18421.62		4.43				2.78		6.54	
MO-P-478-312-97	PW	38.97	-77.15	02140207	Cabin John Creek	CABIN JOHN CR	3	15988.57		2.78				1.67		8.15	44.18
MO-P-480-326-97	PW	38.98	-77.16	02140207	Cabin John Creek	CABIN JOHN CR	3	12988.76		1.89				1.89	19.16		43.68
MO-P-489-314-97	PW	39.09	-77.03	02140205	Anacostia River	NORTHWEST BR	3	8231.35		3.89				1.89		6.78	
MO-P-489-323-97	PW	39.09	-77.02	02140205	Anacostia River	NORTHWEST BR	3	8735.05		2.56				1.67		8.36	
MO-P-496-215-97	PW	39.13	-77.47	02140202	Potomac River (Montgomery County)	BROAD RUN	2	807.4		1.86				3.67	27.11		
MO-P-501-105-97	PW	39.03	-77.19	02140207	Cabin John Creek	CABIN JOHN CR UT1	1	60.43						1.44	3.15	6.37	
PG-N-065-103-97	PW	38.92	-76.89	02140205	Anacostia River	CATTAIL BR	1	1867.43		1.50				1.29	5.16	9.34	58.87
PG-N-068-125-97	PW	38.73	-76.87	02140203	Piscataway Creek	PISCATAWAY CR UT2	1	1671.47		3.50				2.71	16.48		
PG-N-117-329-97	PW	39.00	-76.98	02140205	Anacostia River	NORTHWEST BR	3	19458.99		2.33				1.57		8.70	29.60
PG-N-125-218-97	PW	38.92	-76.90	02140205	Anacostia River	BEAVERDAM CR	2	5016.8		3.25				1.57		6.85	68.36
PG-N-125-228-97	PW	38.92	-76.90	02140205	Anacostia River	BEAVERDAM CR	2	5012.32		2.50				1.29			68.36
PG-N-163-111-97	PW	39.02	-76.83	02140205	Anacostia River	BEAVERDAM CR	1	288.14						1.86	7.79	6.02	28.34
PG-N-171-309-97	PW	38.96	-76.97	02140205	Anacostia River	NORTHWEST BR	3	29984.83		3.50				1.00		9.41	41.96
PG-N-201-330-97	PW	38.96	-76.97	02140205	Anacostia River	NORTHWEST BR ANACOSTIA R	3	22549.76		3.75				1.00		9.73	34.16
PG-N-232-321-97	PW	38.71	-76.96	02140203	Piscataway Creek	PISCATAWAY CR	3	24814.94		3.25				2.43			

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
MO-P-108-123-97	PW						5.25						X		X						8	4					0.00		PK	1				
MO-P-129-114-97	PW	88.38					5.51										10		9	6	6							FR	TG	8			9.50	
MO-P-129-131-97	PW	89.38					5.36												8	4	10		10					OF	FR				8.50	
MO-P-153-113-97	PW						2.47												9	8	7							TG	PV	5			13.00	
MO-P-159-110-97	PW																		7		6						11.00	FR	LN	2			11.00	
MO-P-182-325-97	PW												X					8			8		7				0.00		SL	1				
MO-P-258-213-97	PW																		10									FR	FR	6			14.50	
MO-P-269-203-97	PW						2.35						X	X								1					0.00		PV	0	8		19.75	
MO-P-304-127-97	PW						2.13												10		9		5					LN	HO	2			13.75	
MO-P-308-117-97	PW																		10	7			6				12.00	FR	LN	1	4		19.00	
MO-P-310-313-97	PW																		9	8								FR	FR	8				
MO-P-316-205-97	PW																				9		8					LN	LN	2	5			
MO-P-436-226-97	PW								25.17								5	6	7	3	6	4					0.00		GR	5		19.00	9.50	
MO-P-437-206-97	PW						2.66																10					FR	FR	4				
MO-P-468-109-97	PW						2.62									X			9		7							FR	FR	5	8		15.50	
MO-P-474-317-97	PW																			10								FR	CP					
MO-P-478-312-97	PW																											FR	PV	7				
MO-P-480-326-97	PW												X						10		9	2					12.00	TG	PV	3	5			
MO-P-489-314-97	PW												X					9			6							FR	FR	8				
MO-P-489-323-97	PW																	7			10	5	4					FR	FR	10				
MO-P-496-215-97	PW				199.00	AGR	2.55											5	10		6	7	10					FR	PV	5			16.00	
MO-P-501-105-97	PW								33.13								8	8	2	6	0	9					7.00	LN	PA	3			9.25	
PG-N-065-103-97	PW								38.61				X				2	5	5	1	5	0				10	0.00		LN	1	2	6.00	4.25	
PG-N-068-125-97	PW																7	1	5	7	4	1		100	20	5		EM	TG	10				
PG-N-117-329-97	PW												X	X								5					0.00		PV	4	10			
PG-N-125-218-97	PW								30.97				X	X				3			5		10				0.00		PV	1	1			
PG-N-125-228-97	PW								31.50				X					4	10		2						0.00		PV	1	1			
PG-N-163-111-97	PW				182.00	AD	4.71										5	3	6	3	6			100				FR	FR			16.00	8.75	
PG-N-171-309-97	PW												X					8	10		1	6				20		LN	PV	6	2			
PG-N-201-330-97	PW												X									8					12.00	LN	PV	0				
PG-N-232-321-97	PW																	10										FR	FR					

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
PG-N-246-219-97	PW	38.83	-76.93	02140201	Potomac River (Upper-tidal)	HENSON CR	2	5020.91		3.25				1.86	34.72	7.32	56.26
PG-N-249-128-97	PW	38.76	-76.93	02140203	Piscataway Creek	PEA HILL BR	1	2058.84						2.14			54.44
PG-N-251-305-97	PW	39.03	-76.93	02140205	Anacostia River	LITTLE PAINT BR	3	5793.88		3.25				1.86	37.51	6.57	40.68
PG-N-257-303-97	PW	38.78	-76.98	02140201	Potomac River (Upper-tidal)	HENSON CR	3	11641		3.00				1.00			52.15
PG-N-257-306-97	PW	38.79	-76.96	02140201	Potomac River (Upper-tidal)	HENSON CR	3	9474.21		3.50				1.57		6.60	55.38
PG-N-257-324-97	PW	38.80	-76.96	02140201	Potomac River (Upper-tidal)	HENSON CR	3	9375.61		3.75				2.14			55.63
AA-N-021-112-97	PX	38.89	-76.62	02131104	Patuxent River (Upper)	STOCKETT'S RUN	1	1487.18		3.00				2.71			
AA-N-063-232-97	PX	39.13	-76.77	02131105	Little Patuxent River	DORSEY RUN	2	750.23	57.00	4.25				2.14			
AA-N-092-207-97	PX	39.10	-76.75	02131105	Little Patuxent River	MIDWAY BR	2	1632.48		2.50				1.00		7.29	37.04
AA-N-092-225-97	PX	39.09	-76.74	02131105	Little Patuxent River	MIDWAY BR	2	1765.89		2.50				1.29		6.89	38.80
AA-N-152-304-97	PX	39.12	-76.78	02131105	Little Patuxent River	DORSEY RUN	3	7728.52		4.25				1.29			33.92
AA-N-152-318-97	PX	39.12	-76.78	02131105	Little Patuxent River	DORSEY RUN	3	7814.24		3.75				1.57			33.84
AA-N-190-101-97	PX	38.81	-76.70	02131102	Patuxent River (Middle)	PATUXENT R UT2	1	230.91						1.29		6.19	
AA-N-307-218-97	PX	39.04	-76.72	02131105	Little Patuxent River	LITTLE PATUXENT R UT2	2	377.47		2.00				1.57	8.88	8.50	
AA-N-321-117-97	PX	39.01	-76.69	02131105	Little Patuxent River	LITTLE PATUXENT R UT1	1	1132.62		2.00				1.86		6.67	37.82
AA-N-337-102-97	PX	39.10	-76.73	02131105	Little Patuxent River	FRANKLIN BR	1	776.5		2.50				1.29	7.71		69.19
AA-S-008-132-97	PX	38.74	-76.61	02131101	Patuxent River (Lower)	HALL CR	1	442.62		2.50				2.71	15.73		
AA-S-024-138-97	PX	38.77	-76.68	02131102	Patuxent River (Middle)	DEEP CR	1	650.53		2.75				3.00			
CA-S-014-134-97	PX	38.70	-76.61	02131101	Patuxent River (Lower)	FOWLER'S MILL BR	1	203.9						1.29	11.05	6.10	29.20
CA-S-089-201-97	PX	38.66	-76.63	02131101	Patuxent River (Lower)	CHEW CR	2	1991.14		2.75				3.00			
CA-S-123-136-97	PX	38.51	-76.63	02131101	Patuxent River (Lower)	BUZZARD ISLAND CR	1	75.55						1.29	19.05		
CA-S-187-133-97	PX	38.59	-76.66	02131101	Patuxent River (Lower)	PATUXENT R UT1	1	1894.6		2.50				2.43	15.73		
CA-S-198-107-97	PX	38.63	-76.62	02131101	Patuxent River (Lower)	COCKTOWN CR UT1	1	375.73		2.50				3.29	23.07		
HO-N-022-104-97	PX	39.12	-76.85	02131104	Patuxent River (Upper)	PATUXENT R UT3	1	427.92		1.89				1.86	41.19	6.80	38.08
HO-N-038-204-97	PX	39.19	-76.80	02131105	Little Patuxent River	DORSEY BR TO LITTLE PATUXENT R	2	1097.07		2.11				2.14			
HO-P-002-321-97	PX	39.25	-76.85	02131105	Little Patuxent River	LITTLE PATUXENT R	3	7074.44		3.67				2.78	28.34		
HO-P-018-106-97	PX	39.24	-77.04	02131108	Brighton Dam	TRIDELPHIA RES UT3	1	405.25		2.33				2.56		6.95	
HO-P-063-203-97	PX	39.20	-76.99	02131108	Brighton Dam	TRIDELPHIA RES UT1	2	1251.11		2.56				4.11			
HO-P-098-224-97	PX	39.21	-76.87	02131105	Little Patuxent River	LITTLE PATUXENT R UT5	2	442.29		2.11				2.78		6.02	30.23
HO-P-143-109-97	PX	39.25	-77.01	02131108	Brighton Dam	TRIDELPHIA RS UT2	1	897.98		2.33				3.22		6.45	
HO-P-169-111-97	PX	39.30	-77.05	02131108	Brighton Dam	CATTAIL BR UT2	1	817.09		1.89				3.67	30.90		

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
PG-N-246-219-97	PW								24.32								9	10	8	8	6					25		FR	FR	8	8			
PG-N-249-128-97	PW																																	
PG-N-251-305-97	PW												X					8	10	7	6						10.00	FR	CP	7	7			
PG-N-257-303-97	PW						4.59																					FR	FR	8				
PG-N-257-306-97	PW								26.12						X												10.00	FR	SL	9				
PG-N-257-324-97	PW								26.86				X		X												12.00	LN	FR	9				
AA-N-021-112-97	PX																7	5				10	6					FR	FR					
AA-N-063-232-97	PX							1.20								X			6		7	5	4					FR	LN	10				
AA-N-092-207-97	PX																6	10					9					LN	PV	1				
AA-N-092-225-97	PX												X	X			6					1					0.00		SL	3	3			
AA-N-152-304-97	PX																	10			5		7					FR	PV	6	10			
AA-N-152-318-97	PX																						7					FR	FR					
AA-N-190-101-97	PX																8					7	8					FR	DI	6	9		18.25	
AA-N-307-218-97	PX							4.30		10.10							6		5	5	5	4			20		3.00	FR	OF	6	1		8.25	
AA-N-321-117-97	PX													X								7	6				0.00		LN	6	6			
AA-N-337-102-97	PX												X	X			3	3	3	10	4	4	10	100		13	0.00		PK	2	6			
AA-S-008-132-97	PX								24.35								4	4	7	8	9	5	6	100				FR	FR				14.50	
AA-S-024-138-97	PX				195.80	AD			26.86								9		9				7					FR	CP				13.25	
CA-S-014-134-97	PX																4	3	7	2	7	5	4					FR	FR	10		13.00	5.75	
CA-S-089-201-97	PX																8	5	9		4			100				FR	FR					
CA-S-123-136-97	PX																4	6	7	7	8	8					0.00		GR	5		11.00	4.50	
CA-S-187-133-97	PX																6	5	5	7	7	5	9	100				FR	FR	8			10.25	
CA-S-198-107-97	PX																5	6	6	7	10	10	7					FR	FR				6.00	
HO-N-022-104-97	PX																		7	8	6		4				14.00	FR	PV	1	5		9.25	
HO-N-038-204-97	PX																		8		9		10					FR	PV	5	8			
HO-P-002-321-97	PX						2.43										7	6				8	9	80				FR	FR	10	10			
HO-P-018-106-97	PX	76.91					7.63												9	9		10	10					FR	GR	7			11.50	
HO-P-063-203-97	PX																					8	9					FR	FR	10				
HO-P-098-224-97	PX																7	10				7					0.00		GR	0	4			PC
HO-P-143-109-97	PX						4.11																8				0.00		PV	0				
HO-P-169-111-97	PX						4.09												8	9			10				0.00		PA	9				

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
HO-P-195-130-97	PX	39.29	-76.84	02131105	Little Patuxent River	PLUMTREE BR UT1	1	101.45						2.56	3.41		54.67
HO-P-208-120-97	PX	39.27	-76.84	02131105	Little Patuxent River	PLUMTREE BR	1	598.11		2.33				2.11	22.18		42.49
MO-P-204-137-97	PX	39.12	-76.91	02131107	Rocky Gorge Dam	ROCKY GORGE RES UT1	1	613.12		2.33				3.67	36.37		
PG-N-007-127-97	PX	39.11	-76.90	02131104	Patuxent River (Upper)	WALKER BR UT1	1	220.78	71.00					1.86	2.56	8.62	33.13
PG-N-041-305-97	PX	38.89	-76.84	02131103	Western Branch	SOUTHWEST BR	3	6978.36		4.00				1.29			42.17
PG-N-071-212-97	PX	38.89	-76.85	02131103	Western Branch	SOUTHWEST BR UT1	2	1364.82		3.25				2.43		7.03	
PG-N-087-115-97	PX	38.94	-76.76	02131103	Western Branch	COLLINGTON BR UT1	1	255.5	70.00					1.29	14.06	6.06	
PG-N-097-121-97	PX	39.00	-76.77	02131104	Patuxent River (Upper)	HORSEPEN BR	1	3532.69		3.50				2.71		6.61	27.40
PG-N-141-215-97	PX	38.90	-76.80	02131103	Western Branch	NORTHEAST BR WESTERN BR	2	5510.39		4.75				2.71	40.66	6.34	
PG-N-141-223-97	PX	38.90	-76.80	02131103	Western Branch	NORTHEAST BR WESTERN BR	2	5150.74		4.75				2.14	33.97	6.73	
PG-N-152-124-97	PX	38.78	-76.78	02131102	Patuxent River (Middle)	SOUTHWEST BR CHARLES BR	1	2814.1		2.75				2.71			
PG-N-190-103-97	PX	38.77	-76.81	02131102	Patuxent River (Middle)	CHARLES BR UT1	1	656.86		1.75				2.43			
PG-N-213-113-97	PX	38.89	-76.77	02131103	Western Branch	BLACK BR	1	1053.48		2.00				2.14	9.72		
PG-N-216-135-97	PX	38.90	-76.85	02131103	Western Branch	SOUTHWEST BR UT1	1	1076.1		1.00				2.14	25.50	7.84	26.02
PG-N-219-324-97	PX	38.89	-76.80	02131103	Western Branch	WESTERN BR	3	18185.7		4.75				2.71		6.84	26.65
PG-N-253-122-97	PX	38.85	-76.85	02131103	Western Branch	RITCHIE BR	1	136.36						2.14		6.30	
PG-N-274-128-97	PX	38.89	-76.68	02131104	Patuxent River (Upper)	HONEY BR	1	1127.35		4.00				2.43			
PG-S-007-108-97	PX	38.61	-76.72	02131101	Patuxent River (Lower)	SUMMERVILLE CR UT1	1	19.75						1.29	21.54	6.23	
PG-S-045-317-97	PX	38.55	-76.72	02131101	Patuxent River (Lower)	SWANSON CR	3	14579.23						2.71			
SM-S-125-142-97	PX	38.34	-76.55	02131101	Patuxent River (Lower)	CUCKOLD CR	1	223.68						2.71	32.03		
BA-P-080-314-97	SQ	39.71	-76.59	02120202	Deer Creek	EBAUGH'S CR	3	4347.61		3.67				2.33			
CE-P-022-316-97	SQ	39.70	-76.19	02120204	Conowingo Dam Susquehanna River	CONOWINGO CR	3	27349.7		4.56				2.56			
CE-P-051-108-97	SQ	39.64	-76.13	02120201	Lower Susquehanna River	SUSQUEHANNA R UT1	1	181.22						2.78	19.48		
CE-P-056-307-97	SQ	39.70	-76.10	02120203	Octoraro Creek	STONE RUN	3	6012.17		4.11				2.78			
HA-P-013-101-97	SQ	39.59	-76.14	02120201	Lower Susquehanna River	HERRING RUN	1	868.27		1.67				2.56			
HA-P-035-208-97	SQ	39.68	-76.56	02120202	Deer Creek	PLUMTREE BR	2	23233.82		2.56				3.67			
HA-P-068-114-97	SQ	39.72	-76.49	02120202	Deer Creek	BIG BR	1	1115.71		2.78				3.44			
HA-P-100-204-97	SQ	39.65	-76.50	02120202	Deer Creek	DEER CR	2	4167.9		4.78				2.56			
HA-P-133-111-97	SQ	39.63	-76.30	02120202	Deer Creek	DEER CR UT1	1	553.7		2.78				3.67	38.29		
HA-P-142-105-97	SQ	39.65	-76.31	02120205	Broad Creek	BROAD CR UT1	1	308		1.67				3.44	22.89		
HA-P-178-202-97	SQ	39.70	-76.47	02120202	Deer Creek	BIG BR	2	4084.09		2.78				4.11			

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
HO-P-195-130-97	PX						2.05										3	5	6	2	6		8					LN	HO	3	8	9.00	5.00	
HO-P-208-120-97	PX						2.09										7	4				7	8				8.00	OF	LN	4			12.25	
MO-P-204-137-97	PX																		9	10		9	8					FR	FR	10			17.75	
PG-N-007-127-97	PX												X				1	2	2	2	0				25		0.00		PV	0	1		6.75	
PG-N-041-305-97	PX								26.09								10	6				7	7	90				FR	LN	6	1			
PG-N-071-212-97	PX								24.83													7	7				0.00		PV	3	5			BC
PG-N-087-115-97	PX																5	5	7	6	5			95			14.00	OF	CP				10.25	
PG-N-097-121-97	PX																8	4				4	3	85				FR	FR	8	9			
PG-N-141-215-97	PX								24.65							X	7	4	8		1	8	5	90			12.00	FR	LN	4	7			
PG-N-141-223-97	PX														X		6	5	9			7	4				0.00		PV	3	9			
PG-N-152-124-97	PX								31.54								7	4				5	4	95			0.00		PV	1				
PG-N-190-103-97	PX				110.50	AD			33.97								7					9	5					FR	FR	8			14.00	
PG-N-213-113-97	PX																2	2	7	6	6	2	1	100				FR	CP				19.25	
PG-N-216-135-97	PX								26.71								7		9	8		7	4					FR	PV	3	5		16.00	
PG-N-219-324-97	PX																				6	6	4	100				FR	FR	9	6			
PG-N-253-122-97	PX								326.95					X			9		10			8	9				0.00		PV	3	7			
PG-N-274-128-97	PX																9		9		9	8	9					FR	FR				10.25	
PG-S-007-108-97	PX				9.50	AD											3		7	9	4							FR	FR				5.25	
PG-S-045-317-97	PX																																	
SM-S-125-142-97	PX				159.60	AD											7		7	6		9	9					FR	FR				10.75	
BA-P-080-314-97	SQ						5.11						X									5	3					FR	FR	9				
CE-P-022-316-97	SQ	80.75					6.95											9								25		FR	FR					
CE-P-051-108-97	SQ						2.28												6		8	6	5					LN	PV	3	7		8.25	
CE-P-056-307-97	SQ						3.95																10				0.00		PV	4				
HA-P-013-101-97	SQ																		7									FR	PV	10				
HA-P-035-208-97	SQ						3.41												8									FR	FR					
HA-P-068-114-97	SQ	78.74					5.94															9						FR	PV	5	9			
HA-P-100-204-97	SQ								28.00																		0.00		PA					
HA-P-133-111-97	SQ						2.22							X					7	10			7				13.00	LN	PV	1				
HA-P-142-105-97	SQ						4.74										10	9	8	10	10							FR	CP				8.00	
HA-P-178-202-97	SQ						4.59																					FR	FR					

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
AL-A-020-228-95	UP	39.62	-78.53	02140512	Town Creek	MAPLE RUN	2	1335.26	7.00	3.57				2.56	0.71	6.25	
AL-A-027-205-95	UP	39.68	-78.43	02140511	Fifteen Mile Creek	TERRAPIN RUN	2	2185.65		1.00				3.22	10.37		
AL-A-027-209-95	UP	39.67	-78.43	02140511	Fifteen Mile Creek	TERRAPIN RUN	2	2428.11		1.29				3.44	5.89		
AL-A-061-125-95	UP	39.64	-78.46	02140511	Fifteen Mile Creek	DEEP RUN UT1	1	112.61						2.33			
AL-A-069-102-95	UP	39.64	-78.50	02140511	Fifteen Mile Creek	WHITE SULPHUR RUN	1	61.98						2.33		6.92	
AL-A-143-226-95	UP	39.66	-78.40	02140511	Fifteen Mile Creek	SPRING LICK HOLLOW	2	1386.92		1.57				4.33	35.43		
AL-A-167-230-95	UP	39.70	-78.46	02140511	Fifteen Mile Creek	PINE LICK	2	2043.51		2.14				4.33	11.36		
AL-A-171-206-95	UP	39.71	-78.48	02140511	Fifteen Mile Creek	PINE LICK	2	373.49		1.00				3.44	2.11		
AL-A-207-307-95	UP	39.69	-78.46	02140511	Fifteen Mile Creek	FIFTEEN MILE CR	3	13170.94		2.71				4.11	4.49		
AL-A-244-227-95	UP	39.64	-78.41	02140511	Fifteen Mile Creek	FLAT RUN	2	802.86		1.00				3.67	9.29		
AL-A-248-213-95	UP	39.55	-78.58	02140512	Town Creek	SAWPIT RUN	2	2496.67		1.57				3.67	5.05		
AL-A-248-234-95	UP	39.55	-78.56	02140512	Town Creek	SAWPIT RUN	2	3134.26		2.14				1.44		6.61	
AL-A-318-126-95	UP	39.69	-78.36	02140510	Sideling Hill Creek	SIDELING HILL CR UT1 TO UT1	1	398.68		1.00	1			3.44			
AL-A-392-316-95	UP	39.71	-78.34	02140510	Sideling Hill Creek	SIDELING HILL CR UT1	3	3392.86		2.71				2.33	25.52		
AL-A-392-318-95	UP	39.71	-78.34	02140510	Sideling Hill Creek	SIDELING HILL CR UT1	3	3419.3		3.57				1.22	34.04		
AL-A-419-106-95	UP	39.69	-78.39	02140511	Fifteen Mile Creek	MUDLICK HOLLOW	1	145.23	73.00		1			2.33	6.61		
AL-A-646-207-95	UP	39.60	-78.44	02140508	Potomac River (Allegany County)	RUBY HOLLOW	2	850.1	19.00	1.00	1			2.33	1.06		
WA-A-022-120-95	UP	39.71	-78.07	02140501	Potomac River (Washington County)	POTOMAC R UT4	1	85.39						2.11		7.37	
WA-A-040-221-95	UP	39.71	-77.99	02140506	Licking Creek	RABBLE RUN	2	810.21		1.00	1			2.33			
WA-A-045-127-95	UP	39.70	-78.27	02140509	Little Tonoloway Creek	LT TONOLOWAY UT1	1	154.57	61.00		1			2.33	4.95	6.07	
WA-A-053-223-95	UP	39.69	-77.94	02140505	Little Concococheague	LT CONOCOCHEAGUE CK	2	2227.15		3.29				1.67		6.26	
WA-A-068-101-95	UP	39.71	-78.32	02140510	Sideling Hill Creek	SIDELING HILL CR UT2	1	163.94			1			2.11	23.62	6.09	
WA-A-101-219-95	UP	39.71	-78.14	02140501	Potomac River (Washington County)	DITCH RUN	2	115.29			1			2.78	0.63		
WA-A-133-204-95	UP	39.64	-78.29	02140508	Potomac River (Allegany County)	LONG HOLLOW	2	1677.91		2.43				4.33			
WA-A-139-235-95	UP	39.72	-78.21	02140509	Little Tonoloway Creek	LT TONOLOWAY CR UT2	2	719.84		1.86				4.11	12.89		
WA-A-144-311-95	UP	39.70	-78.32	02140510	Sideling Hill Creek	BEAR CREEK	3	6526.73		3.57				2.78			
WA-V-003-123-95	UP	39.55	-77.77	02140503	Marsh Run	ST JAMES RUN UT1	1	226.41						1.44	0.58	6.19	
WA-V-006-222-95	UP	39.45	-77.67	02140502	Antietam Creek	LITTLE ANTIETAM CR	2	3488.46		2.71				3.44	36.85		
WA-V-063-201-95	UP	39.69	-77.57	02140502	Antietam Creek	LITTLE ANTIETAM CR UT1	2	1692.77		2.71				2.11			
WA-V-075-220-95	UP	39.59	-77.64	02140502	Antietam Creek	BEAVER CK	2	9304.67		1.86				2.56	6.24	6.89	
WA-V-131-224-95	UP	39.69	-77.68	02140502	Antietam Creek	MARSH RUN	2	14834.72		2.43				3.22		6.21	

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
AL-A-020-228-95	UP				93.73	AD		1.70									1	1	2	1	0		5	90	2			FR	FR				0.00	
AL-A-027-205-95	UP				183.60	AD											6		8	8	7							FR	FR				8.75	
AL-A-027-209-95	UP				175.46	AD											8		7		7			100				FR	FR				8.75	
AL-A-061-125-95	UP				33.65	AD																												
AL-A-069-102-95	UP				73.24	AD																												
AL-A-143-226-95	UP				138.19	AD																		100			0.00		SL	10			15.25	
AL-A-167-230-95	UP				131.04	AD											6		7	3	7							FR	FR	10		19.00	5.00	
AL-A-171-206-95	UP				92.90	AD											6		4	2	3			100	15		0.00		PA	6		8.00	5.00	
AL-A-207-307-95	UP				172.95	AD												8	8		0	10		100			0.00		GR	5				
AL-A-244-227-95	UP				144.01	AD		3.80									7	5	3	7	6							FR	FR				6.25	
AL-A-248-213-95	UP																5	2	6	10				100				FR	FR					
AL-A-248-234-95	UP								35.38									5						100		25		FR	PV	4				
AL-A-318-126-95	UP				59.65	AD													9	10								FR	FR				14.00	
AL-A-392-316-95	UP												X	X			10	5	6	8		5				20	0.00		PV	3	8		13.25	
AL-A-392-318-95	UP												X	X	X			10		9	10						0.00		PV	3	9			
AL-A-419-106-95	UP																5	5	6	3	6							FR	FR			14.00	5.00	
AL-A-646-207-95	UP							2.70									2	1	2	1	0				2		2.00	FR	DI	2		9.00	2.00	
WA-A-022-120-95	UP																																	
WA-A-040-221-95	UP		4.60	4.64	-26.08	AD																						FR	FR					
WA-A-045-127-95	UP				101.92	AD											3	2	3	5	6		8					FR	FR				3.75	
WA-A-053-223-95	UP															X		4										FR	PV					
WA-A-068-101-95	UP				92.49	AD											10		6	8	10							FR	FR			16.00	7.50	
WA-A-101-219-95	UP						4.99		27.30								1	1	2	1	2	2	6	100				FR	FR			7.00	1.00	
WA-A-133-204-95	UP																	7									7.00	TG	DI	10			19.00	
WA-A-139-235-95	UP								67.82									5	6		7							LN	FR				8.25	
WA-A-144-311-95	UP				182.92	AD																					8.00	TG	SL					
WA-V-003-123-95	UP	88.82					5.93		27.91				X				1	0	2		0	1	8	100		10	0.00		DI	6	9			
WA-V-006-222-95	UP						2.11											3	8	10		5	10				0.00		PA					
WA-V-063-201-95	UP						3.38												7	10							0.00		CP	6			18.00	
WA-V-075-220-95	UP												X				5	2			0	3					0.00		PV	1				
WA-V-131-224-95	UP	90.40					8.24		33.20				X									2		100				TG	CP		8			

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
WA-V-174-236-95	UP	39.70	-77.68	02140502	Antietam Creek	MARSH RUN	2	10642.91		2.14				2.33			
WA-V-175-208-95	UP	39.63	-77.85	02140504	Conococheague	MEADOW BROOK	2	5283.01		2.14				4.11	22.18		
WA-V-175-216-95	UP	39.65	-77.86	02140504	Conococheague	MEADOW BROOK	2	3865.97		2.43				3.67			
WA-V-176-109-95	UP	39.43	-77.77	02140501	Potomac River (Washington County)	POTOMAC R UT6	1	643.35		1.00				1.44	11.16		
WA-V-192-115-95	UP	39.67	-77.72	02140502	Antietam Creek	HAMILTON RUN	1	1597.24		1.00				1.89	2.91	6.49	61.90
WA-V-193-110-95	UP	39.57	-77.82	02140501	Potomac River (Washington County)	POTOMAC R UT5	1	1728.9		1.00	1			2.33	1.25	6.41	
AA-N-012-110-97	WC	38.87	-76.61	02131004	West River	MUDDY CR	1	255.63	70.00		1			1.00	6.89		
AA-N-034-206-97	WC	39.02	-76.48	02131002	Severn River	MILL CR	2	1442.56		3.00				1.57			
AA-N-072-103-97	WC	38.97	-76.63	02131003	South River	TARNANS BR	1	947.54		4.00				2.14			
AA-N-075-122-97	WC	39.04	-76.63	02131003	South River	BACON RIDGE BR UT1 TO UT1	1	28.74	70.00		1			1.86	2.59		
AA-N-091-320-97	WC	39.11	-76.66	02131002	Severn River	SEVERN RUN	3	7434.73		2.50				3.00			30.33
AA-N-120-102-97	WC	39.09	-76.50	02131001	Magothy River	BLACKHOLE CR	1	406.88	70.00	1.75				1.29	10.62		
AA-N-135-301-97	WC	39.11	-76.67	02131002	Severn River	SEVERN RUN	3	4910.37		3.25				2.71			30.97
AA-N-160-215-97	WC	39.11	-76.56	02131001	Magothy River	MAGOTHY R	2	3099.11		4.00				2.14		6.28	30.21
AA-N-162-216-97	WC	39.11	-76.70	02131002	Severn River	SCHULTZ RUN	2	695.59		3.25				2.71	37.77	6.73	
AA-N-201-203-97	WC	39.08	-76.63	02131002	Severn River	JABEZ BR	2	3364.1		2.00				1.86			
AA-N-209-104-97	WC	39.12	-76.55	02131001	Magothy River	MAGOTHY R UT1	1	265.31						1.29	33.24		76.43
AA-N-211-101-97	WC	38.89	-76.59	02131004	West River	MILL SWAMP BR	1	107.36	15.00		1			1.86	2.73	6.40	
AA-N-230-302-97	WC	39.10	-76.69	02131002	Severn River	SEVERN RUN	3	2754.8		3.00				1.86			26.53
AA-N-230-307-97	WC	39.11	-76.70	02131002	Severn River	SEVERN RUN	3	2569.85		2.50				1.57		6.76	28.24
AA-N-230-313-97	WC	39.11	-76.70	02131002	Severn River	SEVERN RUN	3	2520.82		3.25				2.14			28.24
AA-N-230-319-97	WC	39.11	-76.70	02131002	Severn River	SEVERN RUN	3	714.69		2.75				2.43		6.41	
AA-N-250-217-97	WC	39.00	-76.63	02131003	South River	NORTH R	2	2645.03						2.71		6.91	
AA-N-258-121-97	WC	39.03	-76.60	02131002	Severn River	DEEP DITCH BR	1	90.09			1			2.71	12.06		26.44
AA-N-278-109-97	WC	39.04	-76.64	02131003	South River	BACON RIDGE BR	1	507.59						1.29			
AA-N-281-310-97	WC	39.10	-76.64	02131002	Severn River	SEVERN RUN	3	9800.11		2.75				4.43			28.35
AA-N-281-311-97	WC	39.10	-76.64	02131002	Severn River	SEVERN RUN	3	9914.58		3.00				2.71			28.03
AA-S-037-214-97	WC	38.85	-76.56	02131004	West River	LERCH CR	2	1372.5						1.00			
CA-S-012-119-97	WC	38.54	-76.55	02131005	West Chesapeake Bay	PARKER CR UT1	1	253.91						1.57	33.97		
CA-S-019-111-97	WC	38.69	-76.59	02131005	West Chesapeake Bay	FISHING CR UT1	1	143.35			1			1.57	8.62		
CA-S-053-212-97	WC	38.53	-76.55	02131005	West Chesapeake Bay	PARKER CR	2	4128.66		2.50				2.43			

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
WA-V-174-236-95	UP	92.53					7.20		32.47								8	1	9			1	7				7.00	FR	CP	10				
WA-V-175-208-95	UP	86.86					6.44											2	8				10	100		20	0.00		PA	8				
WA-V-175-216-95	UP	88.56					4.56							X				5						100			0.00		PV	1				
WA-V-176-109-95	UP	86.42					6.63		25.91									1	9		10	3		100				TG	CP	6	6		9.25	
WA-V-192-115-95	UP						5.23		46.78				X	X			5	3	6	6		5	5	100			0.00		PV	1	1		19.00	
WA-V-193-110-95	UP	86.93					2.72		29.46								1	1	6	3	3	1	6	100		5	0.00		PA	6		12.00	8.75	
AA-N-012-110-97	WC								31.37								6	4	4	6	7	7	8	90			5.00	OF	PA	6	9	9.00	4.75	
AA-N-034-206-97	WC																					10		85				FR	FR	6	5			
AA-N-072-103-97	WC																		10			6	3					FR	LN	5	10		16.75	
AA-N-075-122-97	WC				43.80	AD											5	3	3	3	6	5		100				FR	FR	6	3	6.00	3.00	
AA-N-091-320-97	WC																		10			9	7	100				FR	FR					
AA-N-120-102-97	WC		4.00		-108.80	AD		0.70									9	6	1	8	0			98				FR	HO	5	8		18.50	
AA-N-135-301-97	WC																10	10	10			10		100				FR	FR		9			
AA-N-160-215-97	WC																											FR	PV	4	4			
AA-N-162-216-97	WC							4.90		8.50									5	10	7	9	6					FR	FR	5				
AA-N-201-203-97	WC																		10	10		5	5					FR	FR				13.25	
AA-N-209-104-97	WC						2.72							X			10	5	10	10		9		95			0.00		CP	5			16.25	
AA-N-211-101-97	WC	89.06						3.60									2	1	2	2	1	1	6	100	20		0.00		PA	4		16.00	2.00	
AA-N-230-302-97	WC																8	7			10	10	4					FR	PV	6	1			
AA-N-230-307-97	WC													X			10	10			10		6					FR	FR	6	6			
AA-N-230-313-97	WC																				10		9				10.00	FR	HO	2	5			
AA-N-230-319-97	WC																				10		8					FR	HO	2	8			
AA-N-250-217-97	WC				0.60	AD																												
AA-N-258-121-97	WC																9	5	5	7	10	7	5	95				FR	FR		5		7.00	
AA-N-278-109-97	WC																																	
AA-N-281-310-97	WC																					10		95				FR	FR					
AA-N-281-311-97	WC																							100				FR	FR					
AA-S-037-214-97	WC				127.70	AD			27.12																									
CA-S-012-119-97	WC																		10	7	10			100				FR	FR			15.00	7.50	
CA-S-019-111-97	WC																9		2	5	6	10		100				FR	FR			6.00	3.50	
CA-S-053-212-97	WC																		6		0			100				FR	FR					

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
CA-S-074-218-97	WC	38.52	-76.57	02131005	West Chesapeake Bay	PARKER CR	2	1839.88		2.75				1.57	39.08		
CA-S-086-209-97	WC	38.61	-76.52	02131005	West Chesapeake Bay	PLUM POINT CR	2	2549.22		2.75				3.29			
CA-S-119-210-97	WC	38.64	-76.55	02131005	West Chesapeake Bay	FISHING CR	2	637.92		1.50				2.43	18.88		
CA-S-119-211-97	WC	38.64	-76.56	02131005	West Chesapeake Bay	FISHING CR	2	682		1.50				2.71	17.57		
CA-S-171-114-97	WC	38.62	-76.53	02131005	West Chesapeake Bay	PLUM POINT CR UT1	1	187.82	72.00		1			1.00	28.31		
CA-S-200-213-97	WC	38.69	-76.58	02131005	West Chesapeake Bay	FISHING CR UT1	2	568.74		1.50				2.14	29.22		
GA-A-010-205-95	YG	39.46	-79.33	05020203	Deep Creek Lake	DEEP CREEK LAKE UT1	2	507.68		1.57				3.44	2.74	6.22	
GA-A-011-301-97	YG	39.55	-79.31	05020203	Deep Creek Lake	CHERRY CR	3	7246.34		1.00				1.44	11.36		
GA-A-011-317-97	YG	39.55	-79.30	05020203	Deep Creek Lake	CHERRY CR	3	7128.99		1.29				2.11	9.46		
GA-A-030-213-97	YG	39.70	-79.01	05020204	Casselman River	PINEY CR	2	7633.63		3.86				2.33	32.67	6.67	
GA-A-050-201-97	YG	39.38	-79.39	05020201	Youghiogheny River	TROUT RUN	2	4247.02		2.14				3.22			
GA-A-111-316-95	YG	39.40	-79.37	05020202	Little Youghiogheny River	LITTLE YOUGHIOGHENY R	3	8311.43		2.71				3.67	38.29		
GA-A-143-105-97	YG	39.59	-79.28	05020203	Deep Creek Lake	CHERRY CR	1	1440.33		1.00	1			1.00			
GA-A-181-303-95	YG	39.39	-79.47	05020201	Youghiogheny River	SNOWY CR	3	14674.71		1.57				2.78	39.75		
GA-A-185-309-95	YG	39.36	-79.45	05020201	Youghiogheny River	CHERRY CR	3	10065.64		2.71				3.89		6.08	
GA-A-185-321-95	YG	39.36	-79.45	05020201	Youghiogheny River	CHERRY CR	3	10157.81		2.71				3.89			
GA-A-195-203-95	YG	39.39	-79.38	05020201	Youghiogheny River	LITTLE YOUGHIOGHENY R UT2	2	1089.77		3.00				2.78			
GA-A-235-215-95	YG	39.51	-79.25	05020203	Deep Creek Lake	NORTH GLADE RUN	2	2306.36		1.29				3.22	2.58		
GA-A-251-217-97	YG	39.70	-79.45	05020201	Youghiogheny River	CHERRY CR	2	1958.73		1.86				3.00	2.80	6.16	
GA-A-358-115-95	YG	39.71	-78.98	05020204	Casselman River	PINEY CR UT2	1	1031.98		2.71				4.11	37.33		
GA-A-368-116-97	YG	39.55	-79.39	05020201	Youghiogheny River	HOYES RUN	1	867.92						2.78			
GA-A-405-112-95	YG	39.44	-79.36	05020202	Little Youghiogheny River	KINGS RUN	1	456.78		2.71				4.11	8.46		
GA-A-407-312-97	YG	39.63	-79.23	05020204	Casselman River	NORTH BR CASSELMAN R	3	10593.75		2.71				3.22			
GA-A-409-102-97	YG	39.69	-79.38	05020201	Youghiogheny River	YOUGHIOGHENY R UT1	1	868.32		2.43		1		3.67	34.96		
GA-A-420-323-95	YG	39.46	-79.43	05020201	Youghiogheny River	HERRINGTON RUN	3	7953.19		3.00		1		1.89	30.03		
GA-A-420-325-95	YG	39.46	-79.43	05020201	Youghiogheny River	HERRINGTON RUN	3	7989.03		2.71		1		1.67	12.89		
GA-A-432-320-95	YG	39.65	-79.30	05020201	Youghiogheny River	BEAR CREEK	3	10216.71		4.14		1		2.33		6.42	
GA-A-439-205-97	YG	39.59	-79.21	05020204	Casselman River	SOUTH BR CASSELMAN R	2	1435.14		3.57		1		2.11			
GA-A-443-112-97	YG	39.49	-79.47	05020201	Youghiogheny River	BULL GLADE RUN	1	422.89		1.00	1			2.11	35.90		
GA-A-450-113-97	YG	39.71	-79.11	05020204	Casselman River	CASSELMAN R UT1	1	610.25		2.71		1		3.22	15.91		
GA-A-505-210-95	YG	39.59	-79.25	05020204	Casselman River	N BR CASSELMAN R	2	5301.74		2.71				3.67	16.75		

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
CA-S-074-218-97	WC																		5	10				100				FR	FR				18.00	
CA-S-086-209-97	WC																		10	10		3		100				FR	FR				16.00	
CA-S-119-210-97	WC																		4	7	8	6	3	98				FR	FR			16.00	10.50	
CA-S-119-211-97	WC																		4	8	10	8	10	98				FR	FR				5.00	
CA-S-171-114-97	WC																		5	6	7							FR	FR	8	10	16.00	2.75	
CA-S-200-213-97	WC																		5	9	8	8	6	100				FR	LN				6.50	
GA-A-010-205-95	YG														X		5	1	6	4	2	5					0.00		PA			19.00	9.75	
GA-A-011-301-97	YG				25.40	AMD			42.15		X							3			2							FR	PV	5	5			
GA-A-011-317-97	YG				37.20	AMD			42.56									3	9		0	5				10		FR	FR					
GA-A-030-213-97	YG				172.80	AD							X						7	8	5	6						FR	FR	5	9		19.25	
GA-A-050-201-97	YG																	7	10			5	8				0.00		PA	6	8			
GA-A-111-316-95	YG																	4	9		4	5						TG	RR					
GA-A-143-105-97	YG				-6.30	AMD			27.16		X							5				5					0.00		PA	7				
GA-A-181-303-95	YG								27.59						X			8	10								0.00		SL	3	6			
GA-A-185-309-95	YG														X			9				8	8			15		FR	FR					
GA-A-185-321-95	YG												X					5				4	5				0.00		PA					
GA-A-195-203-95	YG												X						10								8.00	FR	HO	6			16.50	
GA-A-235-215-95	YG				158.04	AD											5	3	5		0	2	10					FR	FR					
GA-A-251-217-97	YG				195.60	AMD & AD											10	5	8		0	5		100			0.00		PA	3				
GA-A-358-115-95	YG				176.95	AD													9	10	10	5					9.00	FR	PA				15.00	
GA-A-368-116-97	YG																																	
GA-A-405-112-95	YG																6	2	6	10	8	4	10				0.00		PA	5	6	15.00	5.50	
GA-A-407-312-97	YG				68.70	AMD & AD										X						5						OF	OF	3				
GA-A-409-102-97	YG				44.40	AD													8	8								LN	HO	4			8.50	
GA-A-420-323-95	YG				47.69	AD												5			6	5						FR	FR				13.75	
GA-A-420-325-95	YG				17.30	AD												5	6		2	5						FR	FR		10		13.00	
GA-A-432-320-95	YG				161.01	AD																						PA	PV	2				
GA-A-439-205-97	YG				181.20	AMD			43.44										9	10								FR	TG					
GA-A-443-112-97	YG		4.77	4.43	-25.20	AD											10	10	8	7								FR	FR				16.00	
GA-A-450-113-97	YG																10		7	7	6							FR	FR				8.25	
GA-A-505-210-95	YG				110.87	AMD & AD												3	10		1	8					0.00		FR					

Table F-1. Continued

Site	Basin	Latitude	Longitude	Watershed 8-Digit Code	MD Watershed Name	Stream Name	Stream Order	Catchment Area (acres)	Segment Length Sampled (m)	FIBI	Fish Captured ?	Brook Trout?	Blackwater?	BIBI	PHI	Hilsenhoff Index	% Urban Land Use
GA-A-511-322-95	YG	39.61	-79.24	05020204	Casselman River	N BR CASSELMAN R	3	8420.67		3.29		1		2.78			
GA-A-521-108-95	YG	39.70	-79.29	05020201	Youghiogheny River	MILL RUN	1	1860.78		1.86				4.56	18.84		
GA-A-547-108-97	YG	39.56	-79.46	05020201	Youghiogheny River	SALT BLOCK RUN	1	2612.78		1.86				4.11	11.57		
GA-A-548-317-95	YG	39.55	-79.29	05020203	Deep Creek Lake	CHERRY CR	3	2336.5		1.00				1.67	17.04		
GA-A-551-227-95	YG	39.62	-79.32	05020201	Youghiogheny River	S BR BEAR CR UT2	2	1282.05		1.29				3.44	3.34		
GA-A-563-318-95	YG	39.46	-79.45	05020201	Youghiogheny River	HERRINGTON CR	3	7055.65		2.43				3.22	14.33		

Table F-1. Continued

Site	Basin	% Agricultural Land Use	pH Spring	pH Summer	ANC (ueq/L)	Acid Source	Nitrate Nitrogen (mg/L)	DO (ppm)	Sulfate (mg/L)	DOC (mg/L)	Surface Mine	Landfill	Channelized	Storm Drain	Effluent Discharge	Beaver Pond	Instream Habitat	Epifaunal Substrate	Velocity/Depth Diversity	Pool/Glide/Eddy Quality	Riffle/Run Quality	Channel Alteration	Bank Stability	Embeddedness (%)	Channel Flow Status (%)	Shading (%)	Riparian Buffer Width (m)	Riparian Buffer Land Type	Adjacent Land Type	Remoteness Rating	Aesthetic Rating (0-20)	Maximum Depth (cm)	Average Thalweg Depth (cm)	Stream Block Type
GA-A-511-322-95	YG				51.45	AMD & AD													10									FR	FR				18.00	
GA-A-521-108-95	YG				161.93	AMD & AD													7		6							FR	FR				19.25	
GA-A-547-108-97	YG																	6	10		7	5		100		15		FR	FR					
GA-A-548-317-95	YG				43.50	AMD			52.48		X								10		5	4		100				TG	FR					
GA-A-551-227-95	YG														X		6	2	7		5	4						OF	PV	8	6		14.75	
GA-A-563-318-95	YG				13.07	AD												5			7	3		100			0.00		PV	1				

Table F-2. Key to stressor matrix for 1995-1997 MBSS	
Basin:	
YG	Youghiogheny
NO	North Branch Potomac
UP	Upper Potomac
MP	Middle Potomac
PW	Potomac Washington Metro
LP	Lower Potomac
PX	Patuxent
WC	West Chesapeake
PP	Patapsco
GU	Gunpowder
BU	Bush
SQ	Susquehanna
EL	Elk
CR	Chester
CK	Choptank
NW	Nanticoke/Wicomico
PC	Pocomoke
Fish captured:	
1=No	
Brook Trout:	
1=Brook trout captured at sight	
Blackwater Stream:	
1=Blackwater stream	
Acid Source:	
AGR	Agriculture
AD	Acid deposition
ORG	Organics
AMD	Acid Mine Drainage
Riparian Buffer Type/Adjacent Land Type	
FR	Forest
OF	Old Field
EM	Emergent Vegetation
LN	Mowed Lawn
TG	Tall Grass
LO	Logged Area
SL	Bare Soil
RR	Railroad
PV	Paved Road
PK	Parking Lot/Industrial/Commercial
GR	Gravel Road
DI	Dirt Road
PA	Pasture
OR	Orchard
CP	Cropland
HO	Housing
Stream Blockage Type	
AC	Arch Culvert
BC	Box Culvert
DM	Dam
GW	Gaging Station Weir
PC	Pipe Culvert

APPENDIX G

Watersheds, Major River Basins, and Tributary Strategies Basins in Maryland

Table G-1. Watersheds, major river basins, and Tributary Strategies basins in Maryland (refer to Figures 2-1, 13-1 and 13-2)

Watershed No.	Name	Maj.River Basin	Trib. Strat. Basin	Watershed No.	Name	Maj.River Basin	Trib. Strat. Basin	Watershed No.	Name	Maj.River Basin	Trib. Strat. Basin
1	Conewego Creek	N/A	N/A	46	Bohemia River	EL	UES	94	Potomac River M tidal	LP	LPR
2	L Susquehanna River	SQ	UWS	47	Upper Elk River	EL	UES	95	St. Mary's River	LP	LPR
3	Deer Creek	SQ	UWS	48	Back Creek	EL	UES	96	Breton Bay	LP	LPR
4	Octoraro Creek	SQ	UWS	49	Little Elk Creek	EL	UES	97	St. Clements Bay	LP	LPR
5	Conowingo Dam Susq R	SQ	UWS	50	Big Elk Creek	EL	UES	98	Wicomico River	LP	LPR
6	Broad Creek	SQ	UWS	51	Christina River	EL	UES	99	Gilbert Swamp	LP	LPR
7	Atlantic Ocean	OC	N/A	52	Northeast River	EL	UES	100	Zekiah Swamp	LP	LPR
8	Assawoman Bay	OC	N/A	53	Furnace Bay	EL	UES	101	Port Tobacco River	LP	LPR
9	Isle of Wight Bay	OC	N/A	54	Sassafras River	EL	UES	102	Nanjemoy Creek	LP	LPR
10	Sinepuxent Bay	OC	N/A	55	Stillpond-Fairlee	EL	UES	103	Mattawoman Creek	LP	LPR
11	Newport Bay	OC	N/A	56	Bush River	BU	UWS	104	Potomac River U tidal	PW	MPR
12	Chincoteague Bay	OC	N/A	57	Lower Winters Run	BU	UWS	105	Potomac River MO Cnty	PW	MPR
13	Pocomoke Sound	PC	LES	58	Atkisson Reservoir	BU	UWS	106	Piscataway Creek	PW	MPR
14	Lower Pocomoke River	PC	LES	59	Bynum Run	BU	UWS	107	Oxon Creek	PW	MPR
15	Upper Pocomoke River	PC	LES	60	Aberdeen Proving Ground	BU	UWS	108	Anacostia River	PW	MPR
16	Dividing Creek	PC	LES	61	Swan Creek	BU	UWS	109	Rock Creek	PW	MPR
17	Nassawango Creek	PC	LES	62	Gunpowder River	GU	UWS	110	Cabin John Creek	PW	MPR
18	Tangier Sound	PC	LES	63	Lower Gunpowder Falls	GU	UWS	111	Seneca Creek	PW	MPR
19	Big Annemessex River	PC	LES	64	Bird River	GU	UWS	112	Potomac River FR Cnty	MP	LPR
20	Manokin River	PC	LES	65	Little Gunpowder Falls	GU	UWS	113	Lower Monocacy River	MP	LPR
21	Lower Wicomico River	NW	LES	66	Loch Raven Reservoir	GU	UWS	114	Upper Monocacy River	MP	LPR
22	Monie Bay	NW	LES	67	Prettyboy Reservoir	GU	UWS	115	Double Pipe Creek	MP	LPR
23	Wicomico Creek	NW	LES	68	Middle River - Browns	GU	UWS	116	Catoctin Creek	MP	LPR
24	Wicomico River Head	NW	LES	69	Back River	PP	PBR	117	Potomac River WA Cnty	UP	UPR
25	Nanticoke River	NW	LES	70	Bodkin Creek	PP	PBR	118	Antietam Creek	UP	UPR
26	Marshyhope Creek	NW	LES	71	Baltimore Harbor	PP	PBR	119	Marsh Run	UP	UPR
27	Fishing Bay	NW	LES	72	Jones Falls	PP	PBR	120	Conococheague Creek	UP	UPR
28	Transquaking River	NW	LES	73	Gwynns Falls	PP	PBR	121	Little Conococheague	UP	UPR
29	Honga River	CK	CPK	74	Patapsco River L N Br	PP	PBR	122	Licking Creek	UP	UPR
30	Little Choptank	CK	CPK	75	Liberty Reservoir	PP	PBR	123	Tonoloway Creek	UP	UPR
31	Lower Choptank	CK	CPK	76	S Branch Patapsco	PP	PBR	124	Potomac River AL Cnty	UP	UPR
32	Upper Choptank	CK	CPK	77	Magothy River	WC	LWS	125	Little Tonoloway Creek	UP	UPR
33	Tuckahoe Creek	CK	CPK	78	Severn River	WC	LWS	126	Sideling Hill Creek	UP	UPR
34	Eastern Bay	CR	UES	79	South River	WC	LWS	127	Fifteen Mile Creek	UP	UPR
35	Miles River	CR	UES	80	West River	WC	LWS	128	Town Creek	UP	UPR
36	Wye River	CR	UES	81	West Chesapeake Bay	WC	LWS	129	Potomac River L N Branch	NO	UPR
37	Kent Narrows	CR	UES	82	Patuxent River lower	PX	PTX	130	Evitts Creek	NO	UPR
38	Lower Chester River	CR	UES	83	Patuxent River middle	PX	PTX	131	Wills Creek	NO	UPR
39	Langford Creek	CR	UES	84	Western Branch	PX	PTX	132	Georges Creek	NO	UPR

Table G-1. Cont'd

Watershed No.	Name	Maj.River Basin	Trib. Strat. Basin	Watershed No.	Name	Maj.River Basin	Trib. Strat. Basin	Watershed No.	Name	Maj.River Basin	Trib. Strat. Basin
40	Corsica River	CR	UES	85	Patuxent River upper	PX	PTX	133	Potomac River U N Branch	NO	UPR
41	Southeast Creek	CR	UES	86	Little Patuxent River	PX	PTX	134	Savage River	NO	UPR
42	Middle Chester River	CR	UES	87	Middle Patuxent River	PX	PTX	135	Youghiogheny River	YG	N/A
43	Upper Chester River	CR	UES	88	Rocky Gorge Dam	PX	PTX	136	Little Youghiogheny R	YG	N/A
44	Kent Island Bay	CR	UES	89	Brighton Dam	PX	PTX	137	Deep Creek Lake	YG	N/A
45	Lower Elk River	EL	UES	93	Potomac River L tidal	LP	LPR	138	Casselman River	YG	N/A

Abbreviations for major river basins.

BU - Bush
CK - Choptank
CR - Chester
EL - Elk
GU - Gunpowder
LP - Lower Potomac
MP - Middle Potomac
NO - North Branch Potomac
NW - Nanticoke/ Wicomico
OC - Ocean Coastal
PC - Pocomoke
PP - Patapsco
PW - Potomac Washington Metro
PX - Patuxent
SQ - Lower Susquehanna
UP - Upper Potomac
WC - West Chesapeake
YG - Youghiogheny

Abbreviations for Tributary Strategies basins.

CPK - Choptank
PBR - Patapsco-Back River
LES - Lower Eastern Shore
PTX - Patuxent
LPR - Lower Potomac River
UES - Upper Eastern Shore
LWS - Lower Western Shore
UPR - Upper Potomac River
MPR - Middle Potomac River
UWS - Upper Western Shore

APPENDIX H

Countywide and Watershed-Scale Indicator Estimates

Table H-1. Estimated percentage of stream miles in each fish Index of Biotic Integrity (IBI) category for Maryland counties and for selected watersheds based on 1995-1997 MBSS sampling. Fish IBI scores were grouped into the following categories: 4.0-5.0 good, 3.0-3.9 fair. 2.0-2.9 poor, 1.0-1.9 very poor. Sites with watershed area less than 300 acres were not rated.

	Good	Standard Error	Fair	Standard Error	Poor	Standard Error	Very Poor	Standard Error	Percent Rated	Mean Score	Standard Error
County											
Anne Arundel	7.9	14.1	18.0	37.0	35.0	55.1	8.6	31.8	69.4	2.63	2.08
Allegany	4.1	3.4	8.7	5.8	12.1	13.9	39.6	22.7	64.4	1.79	0.52
Baltimore	13.3	17.9	21.9	21.3	15.3	19.2	15.3	37.0	65.8	2.63	1.73
Baltimore City	0.0	0.0	6.7	46.1	16.5	81.3	76.8	125.1	100.0	1.55	2.73
Calvert	4.1	10.4	0.5	1.8	37.0	56.3	4.3	11.9	45.8	2.65	0.54
Cecil	32.9	35.1	38.5	37.6	14.2	31.1	0.0	0.0	85.5	3.59	0.73
Charles	43.0	18.3	19.6	23.3	2.7	4.9	8.3	17.9	73.6	3.47	1.18
Caroline	5.7	13.2	62.0	124.7	15.5	126.7	0.0	0.0	83.2	3.07	1.29
Carroll	29.4	51.3	32.3	68.3	5.0	17.0	3.9	7.0	70.6	3.69	0.82
Dorchester	3.8	22.6	96.2	22.6	0.0	0.0	0.0	0.0	100.0	3.31	0.65
Frederick	19.3	11.3	20.9	11.5	20.8	17.8	24.7	18.7	85.6	2.75	0.54
Garrett	25.7	19.0	19.9	10.3	9.1	30.5	13.9	19.0	68.5	2.93	2.38
Harford	28.7	19.3	19.4	23.4	21.7	23.4	8.4	18.6	78.1	3.41	0.91
Howard	7.6	6.4	57.4	31.2	19.5	18.4	10.3	14.9	94.9	3.17	0.33
Kent	21.5	70.2	6.9	25.1	6.9	25.1	21.5	70.2	56.9	1.48	2.93
Montgomery	19.8	11.8	22.0	14.4	14.6	12.3	14.2	12.4	70.7	3.11	0.67
Prince George's	21.9	16.8	20.6	14.7	18.2	16.7	14.8	16.9	75.5	3.03	0.77
Queen Anne's	34.7	25.2	36.7	39.5	22.0	33.7	0.0	0.0	93.4	3.56	0.55
Saint Mary's	23.9	30.9	17.0	29.5	8.5	22.5	17.0	29.5	66.4	3.12	1.85
Somerset	0.0	0.0	55.1	83.2	17.3	56.0	0.0	0.0	72.4	2.18	2.42
Talbot	42.2	218.0	26.8	59.0	3.3	22.6	13.8	89.4	86.2	3.58	4.34
Washington	9.9	13.8	25.1	19.5	10.6	7.8	20.6	21.0	66.3	2.55	1.98
Wicomico	4.5	12.4	45.1	46.5	20.0	42.2	0.0	0.0	69.6	2.18	1.47
Worcester	45.7	107.3	52.1	107.1	0.0	0.0	0.0	0.0	97.9	3.64	1.11
Watershed											
Gwynns Falls	11.1	85.1	10.2	22.8	32.8	34.8	7.8	19.4	61.9	2.85	2.85
Mattawoman Creek	44.1	57.3	11.8	27.0	22.1	48.7	22.1	48.7	100.0	3.00	1.56
Seneca Creek	21.5	23.9	26.9	29.7	0.0	0.0	1.5	3.1	49.9	3.92	0.89
Lower Monocacy	28.5	21.9	19.5	13.6	22.0	27.4	9.1	18.6	79.1	3.21	1.07
Upper Monocacy	22.7	20.9	34.5	26.4	7.2	18.8	26.1	28.4	90.5	2.86	1.10
Deep Creek Lake	0.0	0.0	0.0	0.0	0.0	0.0	62.6	171.8	62.6	1.14	1.22

Table H-2. Estimated percentage of stream miles in each benthic Index of Biotic Integrity (IBI) category for Maryland counties and for selected watersheds based on 1995-1997 MBSS sampling. Benthic IBI scores were grouped into the following categories: 4.0-5.0 good, 3.0-3.9 fair. 2.0-2.9 poor, 1.0- 1.9 very poor.

	Good	Standard Error	Fair	Standard Error	Poor	Standard Error	Very Poor	Standard Error	Percent Rated	Mean Score	Standard Error
County											
Anne Arundel	0.2	0.6	15.9	17.9	28.5	40.2	55.4	31.9	100.0	2.05	0.45
Allegany	8.3	8.0	62.1	16.6	22.4	15.7	6.6	5.1	99.4	3.18	0.21
Baltimore	12.1	18.4	47.7	76.7	18.6	23.5	21.6	65.5	100.0	2.95	1.82
Baltimore City	0.0	0.0	0.0	0.0	3.1	9.8	96.9	9.8	100.0	1.27	0.39
Calvert	3.9	9.5	24.4	35.6	20.2	29.6	51.5	45.1	100.0	2.13	0.79
Cecil	7.4	14.8	37.9	35.1	40.6	38.0	14.2	31.0	100.0	2.87	0.48
Charles	20.5	18.3	40.2	20.3	29.5	25.1	8.2	16.6	98.3	3.27	0.52
Caroline	10.7	53.2	8.2	26.2	29.1	54.0	52.0	35.0	100.0	2.20	0.99
Carroll	9.1	42.0	45.0	16.5	27.2	26.7	18.4	26.8	99.6	2.84	1.19
Dorchester	3.8	22.6	48.1	90.7	24.1	78.2	24.1	78.2	100.0	2.63	1.43
Frederick	0.0	0.0	25.7	17.9	31.9	15.9	41.4	19.6	99.0	2.26	0.36
Garrett	28.2	37.4	53.2	16.7	10.7	20.6	7.6	10.3	99.7	3.48	0.72
Harford	6.6	12.5	52.5	51.6	16.8	20.3	19.7	39.1	95.6	2.96	1.14
Howard	20.3	23.0	40.8	36.6	27.8	28.6	9.7	16.1	98.6	3.20	0.35
Kent	17.7	51.3	5.7	20.2	0.0	0.0	76.6	53.8	100.0	2.18	1.32
Montgomery	8.7	10.1	40.7	11.4	23.9	13.9	26.7	14.8	100.0	2.83	0.27
Prince George's	3.0	3.8	9.9	10.8	46.6	10.6	40.5	16.5	100.0	2.19	0.30
Queen Anne's	5.4	8.9	27.2	37.2	33.0	26.7	34.4	35.5	100.0	2.53	0.79
Saint Mary's	10.5	21.2	54.2	35.8	35.3	34.2	0.0	0.0	100.0	3.35	0.48
Somerset	0.0	0.0	21.6	46.7	21.6	46.7	56.8	56.3	100.0	1.98	0.75
Talbot	0.0	0.0	33.1	64.3	35.1	47.4	31.9	40.3	100.0	2.47	0.57
Washington	17.1	14.6	27.7	17.0	37.3	19.4	16.5	16.2	98.6	2.84	0.40
Wicomico	7.8	21.8	12.3	22.0	28.1	35.5	51.3	27.5	99.5	2.23	0.53
Worcester	0.0	0.0	5.7	10.0	3.2	16.0	91.2	20.5	100.0	1.62	0.44
Watershed											
Gwynns Falls	0.0	0.0	13.7	79.8	29.4	55.8	56.8	49.3	100.0	2.07	0.96
Mattawoman Creek	18.1	34.5	18.1	34.5	45.8	43.8	18.1	34.5	100.0	2.92	0.95
Seneca Creek	11.6	21.3	45.2	31.8	23.1	27.9	20.1	27.8	100.0	2.98	0.56
Lower Monocacy	0.0	0.0	43.0	28.8	29.7	21.8	25.2	27.4	97.8	2.65	0.52
Upper Monocacy	0.0	0.0	20.0	25.2	30.6	22.4	49.4	29.1	100.0	2.05	0.55
Deep Creek Lake	0.0	0.0	55.2	238.9	4.9	31.1	39.9	211.6	100.0	2.35	5.16

Table H-3. Estimated percentage of stream miles in each Physical Habitat Index (PHI) category for Maryland counties and for selected watersheds based on 1995-1997 MBSS sampling. PHI scores were grouped into the following categories: 72-100 good, 42-71.9 fair. 12-41.9 poor, 0-11.9 very poor.

	Good	Standard Error	Fair	Standard Error	Poor	Standard Error	Very Poor	Standard Error	Mean Score	Standard Error
County										
Anne Arundel	15.4	16.0	27.0	31.1	34.1	16.2	23.6	35.9	36.21	22.58
Allegany	3.4	3.3	19.0	17.6	33.8	21.8	43.8	23.4	23.27	8.75
Baltimore	31.2	17.2	26.5	38.7	19.2	19.4	23.1	45.7	48.90	20.99
Baltimore City	18.9	24.6	45.4	40.7	12.7	35.1	23.0	65.4	46.46	46.72
Calvert	1.4	5.7	10.1	15.5	66.0	40.1	22.5	38.9	24.02	10.13
Cecil	43.8	38.1	41.8	39.6	14.5	29.8	0.0	0.0	66.37	16.09
Charles	18.6	12.7	37.7	26.0	28.8	26.2	14.9	23.3	44.07	13.58
Caroline	44.2	52.7	9.6	57.1	22.9	115.6	23.3	187.2	53.57	73.66
Carroll	34.5	39.4	32.3	39.2	15.2	19.2	18.0	17.7	52.19	12.71
Dorchester	3.8	22.6	24.1	78.2	48.1	90.7	24.1	78.2	30.63	41.54
Frederick	18.0	7.4	21.1	13.9	32.1	19.5	28.7	19.5	36.83	7.68
Garrett	12.5	35.8	21.8	30.1	34.1	17.1	31.6	18.0	34.31	14.52
Harford	27.6	20.7	43.5	33.1	13.7	19.8	15.2	25.2	55.23	15.23
Howard	25.4	18.8	37.6	23.5	31.0	20.8	6.0	12.5	54.03	14.07
Kent	0.0	0.0	35.4	74.3	21.5	70.2	43.1	82.3	29.37	37.59
Montgomery	5.6	0.0	46.7	17.1	43.6	16.5	4.1	7.6	41.96	5.19
Prince George's	14.2	7.1	36.6	20.2	29.3	21.4	19.9	18.6	40.50	10.94
Queen Anne's	20.8	54.2	24.3	48.0	21.8	36.8	33.1	32.6	38.45	14.80
Saint Mary's	32.4	34.4	0.0	0.0	50.6	34.7	17.0	29.5	41.46	24.07
Somerset	0.0	0.0	27.6	76.7	55.1	83.2	17.3	56.0	25.84	32.54
Talbot	36.6	61.3	16.1	143.3	33.5	89.6	13.8	89.4	44.49	68.80
Washington	11.3	7.8	20.5	18.6	30.6	23.0	37.6	24.6	30.29	10.38
Wicomico	5.6	8.0	23.6	43.4	18.6	42.1	52.3	55.6	24.51	22.46
Worcester	0.0	0.0	93.6	15.4	6.4	15.4	0.0	0.0	59.56	10.96
Watershed										
Gwynns Falls	29.1	55.5	13.7	31.2	0.0	0.0	57.2	83.1	36.17	56.07
Mattawoman Creek	33.8	52.3	44.1	57.3	0.0	0.0	22.1	48.7	56.30	35.75
Seneca Creek	0.0	0.0	45.7	33.3	54.3	33.3	0.0	0.0	39.25	12.99
Lower Monocacy	21.5	14.1	30.6	27.8	38.7	29.0	9.1	18.6	44.33	14.01
Upper Monocacy	18.9	12.7	25.0	21.7	25.0	28.4	31.1	30.0	40.37	14.27
Deep Creek Lake	0.0	0.0	30.8	230.7	4.2	26.6	65.0	208.4	21.51	102.70

Table H-4. Number of sites sampled in the spring and summer by county and by selected watersheds for the 1995-1997 MBSS

	Spring	Summer
County		
Anne Arundel	48	45
Allegany	64	56
Baltimore	78	78
Baltimore City	12	12
Calvert	17	16
Cecil	29	29
Charles	40	39
Caroline	23	20
Carroll	89	87
Dorchester	5	5
Frederick	72	71
Garrett	115	110
Harford	45	42
Howard	41	40
Kent	7	6
Montgomery	65	65
Prince George's	45	41
Queen Anne's	44	41
Saint Mary's	16	15
Somerset	5	4
Talbot	16	11
Washington	40	38
Wicomico	31	28
Worcester	8	6
Watershed		
Gwynns Falls	16	16
Mattawoman Creek	6	5
Seneca Creek	18	18
Lower Monocacy	33	33
Upper Monocacy	36	36
Deep Creek Lake	7	7